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Fuel-Type Classification and Parameters Prediction by Gas Liquid Chromatography Analysis

March 1995

By Donald K. Minus
USA Tank Automotive Command
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There is a research effort that envisions having a vehicle mounted petroleum analysis system that could travel close to the frontlines and would provide rapid test results. This system would quicken results feedback time and increase the scope of analyses by using new technologies that could predict several fuel properties and parameters. One approach under consideration for use in this system is Gas Liquid-Phase Chromatography (GLC).

To simplify the GLC chromatograph of fuel samples, the data was collected as a series of time-segmented regions. These regions were defined to simulate separations by normal alkanes carbon chain length. The GLC data was analyzed with PIROUETTE correlation software (INFOMETRIX, Seattle, WA) to assign the fuel's type and to predict a selected number of fuel's physical properties.

To conduct this study, sixty-seven (67) fuel samples were used of which fifteen were JET A-1/JET As, twelve were JP-4s, nine were JP-8s seven were MOGAS, and three were DF-2s. Preliminary results have included a 100% correct classification as to fuel type and predictions of the 10%, 50%, and 90% distillation, and final boiling point temperatures; and the densities of the samples with relatively low errors of prediction.

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Preface

This endeavor was initiated to determine the feasibility of fuel analysis using Gas Liquid-Phase Chromatography (GLC). The GLC is one of several analytical techniques that is under consideration for use in a proposed petroleum product analyzing system.

Section 1 Introduction

HISTORY OF PROBLEM

With the vast number of fuels the Army may be delivering for use, there is a great need for fuel identification and quality monitoring. When the number of NATO specified fuels, host nation products, and commandeered fuels are also taken into account; a good analytical infrastructure is required to ensure optimal equipment performance and to prevent fuel-related equipment failures due to misapplication. Placing the monitoring function as close as possible to the point of use would enable field commanders to make better informed decision concerning usability without introducing unknown risks.

IMPETUS FOR PQA SYSTEM

Thus was the impetus for the Petroleum Quality Analysis (PQA) program which envisions having vehicle-mounted petroleum analyzing instruments which could travel close to the most forward positions and could provide test results with feed back time in terms of minutes or hours as oppose to days or weeks as is the case with the current mobile petroleum labs. Detailed information concerning the overall mission, the operational concept, and the proposed capabilities of the PQA system is contained in the Mission Need Statement (MNS) and the Operational Requirements Document (ORD) which are included in Appendix A and B respectively.

EXPLANATION OF GLC ANALYSIS

One system under consideration for use in a PQA system is Gas Liquid-Phase Chromatography (GLC). GLC analyzes mixtures by vaporizing the samples and measuring the time required for the mixture's components to be eluted by a mobile phase (carrier gas) through a stationary phase (column coating for capillary columns or packing material in packed columns). Since GLC analysis requires vaporizing a sample, a mixture's components are most easily separated by boiling point temperatures. However, by changing the nature of the stationary phase (i.e. using a packing material or a column coating that has a greater affinity for a particular component or components of the mixture) one can change the elution time of the mixture's components.

Section 2 Background

RESULT OF LITERATURE SURVEY

There are several methods known in literature of efforts to analysis fuel samples using GLC. In a number of the procedures that were retrieved[1-7], the GLC was coupled with another analytical instrument (most often a Mass Spectrum analyzer (MS)) and the goal of the effort was to identify each individual component. These methods are not conducive with the Army's needs in that they require use of specialize test instruments and several chemical standards. Although the results of these analyses gives "fingerprint" representation for each analyzed sample, these analyses are very effort intensive and would be too time consuming for a fuel monitoring effort. Other concerns with these analyses are that they are subject to error due to the overlap of co-eluting components and individual peak identification are tedious due to the complex nature of petroleum products.

There was also several methods in which the GLC was used alone to analyze fuel samples[8,9], along with many standardized test methods which analyzes petroleum products using the GLC[10-17]. In the paper by LePera[18], it was shown that different fuel types and grades could be distinguished by comparing their GLC peak height and peak location. A report by Stavinoha[19] showed that a technique could be developed that would determine the saturate, olefinic, and aromatic hydrocarbon content of fuel using GLC analysis. None of these test method or techniques attempted a wide scope determination of fuel type and prediction of fuel parameters and properties.

In two of the literature retrieval, one by Present et al.[20], and one by Antoine[21], attempts were made at broad base prediction of several fuel properties using GLC data. In the interim report by Present et al., an attempt was to be made to develop a boiling point distribution curve that would be used to calculate the Reid Vapor Pressure (RVP), the ASTM D86[22] distillation boiling point temperatures, the ASTM D1160[23] distillation boiling point temperatures, the America Petroleum Institute (API) gravity, the flash point, and the viscosity. There was no mention made of the results of the predictions and a final report of the effort was not located. In the work by Antoine, estimations were made for the D86 distillation boiling point temperature, the API gravity, the flash point, and the viscosity using D2887 data of thirty two synthetic fuels. Antoine was able to develop good prediction model, that when compared to the actual measured parameters by linear regression gave R squared values of 0.950 to 0.991. One of the drawback with these two method is that both method used sub ambient GLC oven temperatures. In order to achieve these temperature additional hardware for cooling would be required.

APPROACH

Due to the concerns of co-eluding peaks, the strategy for this effort was to look at the fuel GLC chromatograms as a number of distinct time-segmented regions as opposed to individual chromatographic peaks. Such an analysis would eliminate errors due to eluting time variances of individual components and it would simplify the chromatogram into a limited number of data points. Also, a GLC oven temperature program was sought which would not use sub ambient temperatures.

Section 3 Test Plan

SUMMARY OF FUEL USED IN THE STUDY

To conduct this study, sixty-seven (67) fuel samples were used of which fifteen met ASTM D1655, "Standard Specification for Aviation Turbine Fuels"[24], (Jet A-1's or Jet A's); twelve were Grade JP-4 and nine Grade JP-5 fuels meeting Military Specification MIL-T-5624P, "Turbine Fuel, Aviation, Grades JP-4, JP-5, and JP-5/JP-8 ST"[25]; twelve were AVGAS's conforming to ASTM D 910, "Standard Specification for Aviation Gasolines"[26]; nine were JP-8's provided under Military Specification MIL-T-83133, "Turbine Fuels, Aviation, Kerosene Types, NATO F-34 (JP-8 and NATO F-35"[27]; seven were MOGAS meeting Military Specification MIL-G-3056F, "Gasoline, Automotive, Combat"[28]; and, three Grade DF-2 fuels conforming to Federal Specification VV-F-800D, "Fuel Oil, Diesel"[29].

The fuel samples used in the study were obtained from three sources: the Fuels Branch, Fuels and Lubricant Division, Wright-Patterson Air Force Base (WPAFB), OH; Directorate of Aerospace Fuels, Detachment 13 (the Kelly AFB contingent at WPAFB); and the Belvoir Fuels and Lubricants Research Facility (BFLRF) at SwRI, San Antonio, TX. A list of the fuel samples used in the study and the specification test data are given in Appendixes C and D respectively.

DESCRIPTION OF GLC TEST PARAMETERS

The instrument used in the study was the Hewlett Packard model 5890 GC (initial temperature 40°C, with a hold time for 5.0 minutes, a program ramp 6.0°C/ minute, to a final temperature of 250°C, with a hold time 20.0 minutes). A Flame Ionization Detector (FID) was used with a 30 meter megabore column, 0.53 cm inside diameter with a 2.65µm film coat of methyl silicone (HP-1). The carrier gas was helium with a flow rate of 8.6 mL/ minute.

DESCRIPTION OF DATA COLLECTION SYSTEM

The GLC data was collected using PE Nelson's ACCESS*SEC chromatography data collection software. Contained in the ACCESS*SEC software is a PEAK LUMPING function where the chromatograms can be collected as a series of lumped regions and all of the peaks in the regions are assigned to the retention time that has the highest peak height in that region. What this does is to reduce the chromatogram of a fuel sample from several retention time peaks to a selected number of lumped peak regions. This lumped-peak region analysis is more advantageous than the "unlumped" analysis in that the lumped analysis reduces the chromatogram of a fuel sample to a limited number of data points which are more manageable.

The peaks were lumped into regions that were defined to simulate separation by carbon chain length. The time constraints for the 20 regions and the retention time for the normal alkanes are given in Table 1.

Table 1. Time Constraints for Segmented Regions

REGION	n-ALKANE	RETENTION TIME, MIN	TIME BOUNDARIES, MIN
1	C5	1.589	0.00 - 2.27
2	C6	2.937	2.27 - 4.62
3	C7	6.298	4.62 - 8.33
4	C8	10.368	8.33 - 12.24
5	C9	14.117	12.24 - 15.77
6	C10	17.413	15.77 - 18.95
7	C11	20.475	18.95 - 21.87
8	C12	23.261	21.87 - 24.55
9	C13	25.828	24.55 - 27.07
10	C14	28.315	27.07 - 29.37
11	C15	30.412	29.37 - 31.54
12	C16	32.663	31.54 - 33.66
13	C17	34.647	33.66 - 35.64
14	C18	36.645	35.64 - 37.50
15	C19	38.363	37.50 - 39.26
16	C20	40.152	39.26 - 41.44
17	C21	—	41.44 - 44.02
18	C22	—	44.02 - 46.61
19	C23	—	46.61 - 49.19
20	C24	50.476	49.19 - 60.00

Examples of typical GLC chromatograms of fuel samples with both the unlumped and lumped-peak analysis are given in Appendix E and a table of the lumped-peak data for all of the fuel samples is given in Appendix G.

REPEATABILITY OF GLC RESULTS

To consider the repeatability of the lumped-peak method, five fuel samples were randomly selected and the selected fuel samples were repeatedly analyzed. The standard deviation and coefficient of variation were calculated for each of the twenty segmented regions. The samples analyzed were a 90/10 % mixture of JP-4 and DF-2, a 90/10 % mixture of JP-4 and MOGAS, a 90/10 % mixture of JP-4 and JET A, a 90/10 % mixture of DF-2 and MOGAS, and a 90/10% mixture JET A and JP-4. The ratios for the mixed fuel samples were selected to simulate gross or catastrophic type fuel contamination.

For the above samples the average standard deviation was 0.326, and the average coefficient of variation was 0.185 respectively. The table of the overall results is given in the Appendix F.

Section 4 SYMPHONY Test Results

DESCRIPTION OF SYMPHONY SOFTWARE

Once collected and processed, the data was analyzed using SYMPHONY which is a spread sheet program by LOTUS, and PIROUETTE which is a data correlation program by INFOMETRIX.

In the SYMPHONY program the data was considered as twenty independent variables and each variable was multiplied by a constant and the products were summed to give a single number for each analysis. Since the number generated for each sample is a function of the independent variables, the number generated by symphony would be "weighted" by the region or regions that has the largest lumped peak value. Also since similar fuel types should have similar lumped-peak distribution, it was believed that "like" fuel samples would have similar numbers generated from the analysis.

TEST RESULTS

From the SYMPHONY analysis, the numbers generated for the fuel samples ranged from a low of 314.508 which was for an AVGAS sample to a high of 1208.596 which was for a DF-2 sample. In spite of the relatively large separation of the individual fuel samples, similar fuel types were separated by smaller ranges as follow; JET A-1's and JET A's (720.203 to 872.603, average of 795.868); JP-8's (744.048 to 816.487, average 780.976); JP-5's (783.732 to 886.324, average 821.177); JP-4's (479.654 to 641.190, average 570.854); AVGAS's (314.508 to 606.815, average 443.276); MOGAS's (496.475 to 640.576, average 559.852); and DF-2's (1076.904 to 1208.596, average 1155.620).

Based on the numbers generated by the SYMPHONY analysis, the fuel samples could be placed into three groups one consisting of JET A-1, JET A, JP-8, and JP-5 (from 720.203 to 886.324); one consisting JP-4, AVGAS, and MOGAS (from 314.508 to 641.190); and one consisting of DF-2 (from 1076.904 to 1208.596).

A table with all of the number generated by the SYMPHONY analysis is given in Appendix H.

Section 5 PIROUETTE Test Results

DESCRIPTION OF PIROUETTE SOFTWARE

For the PIROUETTE analysis the K-Nearest Neighbor (KNN) classification program and the Partial Least Squares (PLS) correlation program were used. For the analyses the peak area for each of the regions were entered as independent variables, the fuel type was entered as a class variable, and selected measured fuel parameters were entered as dependent variables. The data was then grouped based on similarity of the data set and correlation models were made for 10 %, 50 %, 90 %, and final boiling point temperatures, and the density.

TEST RESULTS

From the initial analysis, samples 93-F-339 (MOGAS), 93-F-591 (JP-4), and 93-F-643 (AVGAS) were identified as statistical outliers from the other samples. These determinations were based on a Hierarchical Cluster Analysis (HCA) which grouped the samples based on the similarity of their GLC data. With a HCA analysis, the three outliers were placed into grouping outside of the other samples of the identical type.

Once the outliers were removed HCA analysis resulted in five groups consisting of AVGAS, JP-4, MOGAS, DF-2, and a combined group of JP-5, JP-8, and JET A. There were no misclassifications and all of the samples were assigned to their proper class.

The class assignments from the KNN model for each of the fuel samples are given in Appendix H.

To test the rigor of the classification model, eighteen randomly selected samples were removed from the data set and a KNN model was made using the remaining data points. The eighteen samples included nine JP-8 group samples, three JP-4, three AVGAS, two MOGAS, and one DF-2. The generated classification model was then applied to the removed samples and resulted in 100 % correct class determination for the samples in the removed set.

A list of the removed samples and their class assignments are given in Appendix I.

MIXED FUEL SAMPLES

To determine the ability of the generated model to classify mixed fuel samples, fifty-six additional samples were made by mixing fuels of two different class from the initial forty-six samples in the data set. The samples were mixed in ratios of 90 % to 10 % and 75 % to 25 % by volumes. As previously stated, the ratios for the mixed fuel samples were selected to simulate gross or catastrophic fuel type contamination.

Except for one, all of the 90 % / 10 % fuel mixtures were classified as belonging to the major component's class. The one exception was a MOGAS / DF-2 mixture which was classified as a JP-4 sample.

For the 75 % / 25 % fuel mixtures, all of the mixtures in which DF-2 and JP-8 group samples were the major component were classified as belonging to the major component's class. For samples in which JP-4 and AVGAS were the major component, all but one of the samples were classified as belonging to the major component's class. All of the samples in which MOGAS was the major component were classified as belonging outside of the MOGAS group.

A list of all of the classification for the mixed fuel data is given in Table 2.

Table 2. Mixed Fuel Analyses Results

NUMBER OF SAMPLES	FUEL MIXTURE	ASSIGNMENT FOR 90%/10% MIX	ASSIGNMENT FOR 75%/25% MIX
1	DF-2/MOGAS	DF-2	DF-2
1	DF-2/JP-4	DF-2	DF-2
1	DF-2/AVGAS	DF-2	DF-2
2	DF-2/JP-8	DF-2	DF-2
1	MOGAS/DF-2	JP-4	JP-4
1	MOGAS/JP-4	MOGAS	JP-4
1	MOGAS/AVGAS	MOGAS	JP-4
2	MOGAS/JP-8	MOGAS	JP-4, JP-8
1	JP-4/DF-2	JP-4	JP-4
1	JP-4/MOGAS	JP-4	JP-4
1	JP-4/AVGAS	JP-4	JP-4
2	JP-4/JP-8	JP-4	JP-4, JP-8
1	AVGAS/DF-2	AVGAS	AVGAS
1	AVGAS/MOGAS	AVGAS	AVGAS
1	AVGAS/JP-4	AVGAS	AVGAS
2	AVGAS/JP-8	AVGAS	AVGAS
1	JP-5/DF-2	JP-8	JP-8
1	JET-A/DF-2	JP-8	JP-8
2	JET-A/MOGAS	JP-8	JP-8
2	JET-A/JP-4	JP-8	JP-8
1	JET-A/AVGAS	JP-8	JP-8
1	JP-8/AVGAS	JP-8	JP-8

ESTIMATION OF FUEL PARAMETERS

The GLC data was also used to develop models to predict the 10 %, 50 %, 90 %, and final boiling point temperatures and the fuel's density. Using the results of the predictions, the residual and % error of the residual from the average were calculated. A review of the errors suggest that the model may be good predictors of the studied parameters. Table 3 is a listing of the residual and % residual for the generated models.

Table 3. Statistical Analysis of Parameter Prediction Using Generated KNN Models

PARAMETERS	JP-8 SEPARATED MODEL[1]		TOTAL MODEL[2]	
	RESIDUAL[3]	% RESIDUAL[4]	RESIDUAL	% RESIDUAL
10% BP TEMP	5.14	2.85	10.2	8.28
50% BP TEMP	3.61	1.70	7.86	4.83
90% BP TEMP	6.39	2.58	11.7	5.67
FINAL BP TEMP	9.68	3.54	16.9	7.02
DENSITY	0.00440	0.546	0.00859	1.10

1. The JP-8 separated model was a correlation model that was developed from samples of the JP-8 group.
2. The total model was a correlation model that was developed from all of the samples.
3. The residual = $((V_c\text{-}V_m)^2)^{0.5}$ where Vc is the calculated value of the parameter and V_m is the measured value of the parameter.
4. The % residual = 100(Residual)/Average V_m.

To test the rigor of the models at predicting parameters of samples that weren't included in the correlation model, five data sets were removed from the correlation models and Partial Least Squares (PLS) regression method were used to predict the listed parameters. Table 4 thru Table 8 are listing of the predicted values and errors of prediction for the five samples.

Table 4. 10% Boiling Point Temperature

SAMPLE NUMBER	ACTUAL VALUE[1], °C	GROUP 1 MODEL[2]		TOTAL MODEL[3]	
		PREDICTED	% ERROR	PREDICTED	% ERROR
93-POSF-2959	176	166	5.68	170	3.41
92-POSF-2934	151	166	9.93	167	10.6
93-POSF-2747	185	186	0.54	195	5.41
93-F-304	202	183	9.41	176	12.9
93-F-668	169	185	9.47	183	8.28

1. The measured point is the parameter's measured value
2. The Group 1 Model is the parameter's predicted value using a model that was developed using data point from the JP-8 group samples.
3. The Total Model is the parameter's predicted value using a model that was developed using data points from all of the samples.

Table 5. 50% Boiling Point Temperature

SAMPLE NUMBER	ACTUAL VALUE[1], °C	GROUP 1 MODEL[2]		TOTAL MODEL[3]	
		PREDICTED	% ERROR	PREDICTED	% ERROR
93-POSF-2959	199	202	1.51	195	2.01
92-POSF-2934	202	205	1.49	192	4.95
93-POSF-2747	193	195	1.04	208	7.77
93-F-304	232	212	8.62	210	9.48
93-F-668	211	213	8.95	217	2.84

1. The measured point is the parameter's measured value
2. The Group 1 Model is the parameter's predicted value using a model that was developed using data point from the JP-8 group samples.
3. The Total Model is the parameter's predicted value using a model that was developed using data points from all of the samples.

Table 6. 90% Boiling Point Temperature

SAMPLE NUMBER	ACTUAL VALUE[1], °C	GROUP 1 MODEL[2]		TOTAL MODEL[3]	
		PREDICTED	% ERROR	PREDICTED	% ERROR
93-POSF-2959	231	243	5.19	238	3.03
92-POSF-2934	249	243	2.41	244	2.01
93-POSF-2747	211	208	1.42	210	0.47
93-F-304	275	260	5.45	251	5.09
93-F-668	260	263	1.15	250	3.85

1. The measured point is the parameter's measured value
2. The Group 1 Model is the parameter's predicted value using a model that was developed using data point from the JP-8 group samples.
3. The Total Model is the parameter's predicted value using a model that was developed using data points from all of the samples.

Table 7. Final Boiling Point Temperature

SAMPLE NUMBER	ACTUAL VALUE[1], °C	GROUP 1 MODEL[2]		TOTAL MODEL[3]	
		PREDICTED	% ERROR	PREDICTED	% ERROR
93-POSF-2959	250	262	4.80	264	5.60
92-POSF-2934	270	254	5.93	270	0.00
93-POSF-2747	236	236	0.00	242	2.54
93-F-304	293	292	0.34	278	5.12
93-F-668	327	316	3.36	280	14.4

1. The measured point is the parameter's measured value
2. The Group 1 Model is the parameter's predicted value using a model that was developed using data point from the JP-8 group samples.
3. The Total Model is the parameter's predicted value using a model that was developed using data points from all of the samples.

Table 8. Density

SAMPLE NUMBER	ACTUAL VALUE[1], °C Kg/m³	GROUP 1 MODEL[2]		TOTAL MODEL[3]	
		PREDICTED	% ERROR	PREDICTED	% ERROR
93-POSF-2959	792	799	0.90	797	0.63
92-POSF-2934	808	796	1.44	796	1.18
93-POSF-2747	807	804	0.36	790	2.11
93-F-304	812	807	0.62	804	0.99
93-F-668	823	810	1.58	813	1.22

1. The measured point is the parameter's measured value
2. The Group 1 Model is the parameter's predicted value using a model that was developed using data point from the JP-8 group samples.
3. The Total Model is the parameter's predicted value using a model that was developed using data points from all of the samples.

Section 6 Conclusion

The PIROUETTE classification program clearly is able to distinguish between JP-4; DF-2; AVGAS; and MOGAS; and one combined group of JET A, JET A-1, JP-5 and JP-8. The difficulty in distinguishing between the JET A, JET A-1, JP-5 and JP-8 stems from the fuels similar boiling point distribution. This deficiency may be rectified by adding additional data points to the test matrix such as Fuel System Icing Inhibitor (FSII) content to separate JET A & JET A-1 from JP-5 and JP-8, whereas JP-5 and JP-8 may be distinguished on the basis of flash point. The SYMPHONY spread sheet analysis was not as selective in separating the fuel classes due to the consideration of the single number generated.

PIROUETTE may be able to predict selected fuel parameters as is evident by the small errors of predictions, especially for the JP-8 group samples. To conclusively confirm the ability of the models to predict fuel parameters, the data base must be expanded to include a larger number of data sets.

Further analysis will be directed at using other columns to perform fuel separation, the use of increased temperatures to reduce analysis time and the use of additional fuel parameters in the PIROUETTE classification and correlations analyses.

References

1. Dworzanski, J. P.; Chapman, J. N.; Meuzelaar, H. L. C.; and H. R. Lander, H. R. "Development of Microscale Reactors Directly Interfaçed to GC/IR/MS Analytical System for High Temperature Pyrolytic Degradation Studies of Jet Fuels in the Gas Phase or Under Supercritical Conditions." Symposium on Structure of Jet Fuels III (Presented before The Division of Petroleum Chemistry, INC., A. C. S., S.F. Meeting, April 5-10, 1992.

2. Mayfield, H. T., and Henley, M. V. "Classification of Jet Fuels Using High Resolution Gas Chromatography and Pattern Recognition." Monitoring Water in the 1990's: Meeting New Challenges, Denver, CO, June 11-14, 1990.

3. Gerry, F. S.; Schubert, A. J.; McNally, M. J.; and Pahl, R. H. "Test Fuels: Formulation and Analyses - The Auto/Oil Air Quality Improvement Research Program." SAE Paper # 920324.

4. Song, C., and Hatcher, P. G. "Compositional Differences Between Coal- and Petroleum-Derived Jet Fuels" Symposium on Structure of Jet Fuels III presented before The Division of Petroleum Chemistry, Inc. ACS, S.F. Meeting, April 5-10, 1992.

5. Schuetzle, D.; Jensen, T. E.; Nagy, D.; Prostak, A.; and Hochhauser, A. "Analytical Chemistry and Auto Emissions." *Analytical Chemistry*, 63, 1149A-1159A, 1991.

6. Burns, V. R.; Benson, J. D.; Hochhauser, A. M.; Koehl, W. J.; Kreucher, W. M.; and Reuter, R. M. *Description of Auto/Oil Air Quality Improvement Research Program*, SAE Paper # 912320.

7. Dworzanski, J. P.; Chapman, J. N.; and Meuzelaar, H. L. C. "Development of Microscale Reactors Directly Interfaced to GC/IR/MS Analytical System for High Temperature Pyrolytic Degradation Studies of Jet Fuels in the Gas Phase or Under Supercritical Conditions." Symposium on Structure of Jet Fuels III presented before The Division of Petroleum Chemistry, Inc. ACS, S.F. Meeting, April 5-10, 1992.

8. Hayes, P. C., and Pitzer, E. W. "Improved Analysis Of Petroleum And Shale-Derived Fuel Distillates By Altering GC Programmed Temperature Rate." AFWAL-TR-85-2027, Fuels Branch, Fuels And Lubrication Division, Aero Propulsion Laboratory, Air Force Wright Aeronautical Laboratories, AFSC, Wright-Patterson Air Force Base, OH 45433.

9. Antoine, A. C. "Use Of Petroleum-Based Correlation And Estimation Methods For Synthetic Fuels." NASA Technical Memorandum 81533.

10. ASTM Method D2267, "Standard Test Method for Aromatic in Light Naphthas and Aviation Gasolines by Gas Chromatography." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

11. ASTM Method D2600, "Standard Test Method for Aromatic Traces in Light Saturated Hydrocarbons by Gas Chromatography." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

12. ASTM Method D2887, "Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

13. ASTM Method D3606, "Standard Test Method for Benzene and Toluene in Finished Motor and Aviation Gasoline by Gas Chromatography." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

14. ASTM Method D3710, "Standard Test Method for Boiling Range Distribution of Gasoline and Gasoline Fractions by Gas Chromatography." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

15. ASTM Method D4420, "Standard Test Method for Aromatic in Finished Gasoline by Gas Chromatography." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

16. ASTM Method D4815, "Standard Test Method for Determination of C_1 to C_4 Alcohols and MTBE in Gasoline by Gas Chromatography." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

17. ASTM Method D5134, "Standard Test Method for Detailed Analysis of Petroleum Naphthas through n-Nonane by Capillary Gas Chromatography." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

18. LePera, M. E. "Identification And Characterization Of Petroleum Fuels Using Temperature-Programmed Gas-Liquid Chromatography." CCL-218, AD 646382, February 1967, Defense Technical Information Center, Cameron Station, Alexandria, VA 22314.

19. Stavinoha, L. L. "Hydrocarbon-Type Analysis Of Gasoline Using Stabilized Olefin Absorption And Gas Chromatography." U.S. Army Fuels and Lubricants Research Laboratory, Final Report AFLRL No. 23, AD 767560, September 1973, Defense Technical Information Center, Cameron Station, Alexandria, VA 22314.

20. Present, D. L.; Newman, F. M.; and Stavinoha, L. L. "Correlation of Chemical Characteristics With Fuel Properties by Gas Chromatography." U.S. Army Fuels and Lubricants Research Laboratory, Interim Report AFLRL No. 153, AD A121708, December 1981, Defense Technical Information Center, Cameron Station, Alexandria, VA 22314.

21. Antoine, A. C. "Evaluation of the Application of Some Gas Chromatographic Methods for the Determination of Properties of Synthetic Fuels." NASA Technical Memorandum 79035. presented at Aerospace meeting sponsored by the Society of Automotive Engineers on 27-30 November 1980.

22. ASTM Method D86, "Standard Test Method for Distillation of Petroleum Products." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

23. ASTM Method D1160, "Standard Test Method for Distillation of Petroleum Products at Reduced Pressures." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

24. ASTM D1655 "Standard Specification for Aviation Turbine Fuels." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

25. Military Specification MIL-T-5624P, "Turbine Fuel, Aviation, Grades JP-4, JP-5, and JP-5/JP-8ST." September 1992.

26. ASTM D910 "Standard Specification for Aviation Gasolines." American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

27. Military Specification MIL-T-83133D, "Turbine Fuels, Aviation, Kerosene Types, NATO F-34 (JP-8) and NATO F-35." January 1992.

28. Military Specification MIL-G-3056F, "Gasoline, Automotive, Combat." November 1991.

29. Federal Specification VV-F-800D, "Fuel Oil, Diesel." October 1987.

Appendix A Mission Need Statement for Petroleum Quality Analysis (PQA)

MISSION NEED STATEMENT
FOR
PETROLEUM QUALITY ANALYSIS (PQA)

1. **Defense Planning Guidance Element.** A PQA capability will resolve a deficiency identified in the Army Modernization Plan, Annex J, January 1993, as well as the Quartermaster Functional Area Assessment, April 1993.

2. **Mission and Threat Analysis.**

a. Mission Analysis. Commanders in today's Force Projection Army require a combat service support (CSS) capability that enhances the sustainment of momentum and operational/tactical maneuver freedom, and optimizes the use of locally available petroleum supplies (either friendly or enemy). America's Army of today is capable of deploying to all corners of the globe regardless of the environment, for warfighting as well as operations other than war. Current shortfall is the inability of combat service support units to test and analyze petroleum products in a timely manner, as far forward as possible in a fast moving fluid scenario, characteristic of a Force Projection Army. This proposed replacement capability for petroleum laboratories at theater level and below will meet this requirement. United States Army petroleum laboratories test petroleum, oils, and lubricant products for adherence to specification tolerances. Maneuver units currently have mobile and airmobile laboratories forward. These laboratories are responsible for testing fuel as it arrives at maneuver units. Testing at this level is primarily concerned with discovering fuel contaminants and determining levels of certain fuel additives. Current procedures require that fuel not be used until it is tested and analyzed for compliance with military specifications. Once complete, the owning unit must be notified of the results of the testing and of any restrictions on the use of the fuel. This process may require up to three days of storage before the fuel can be used. On the modern battlefield, this delay is not tactically feasible. Therefore, a highly mobile modern laboratory is needed. On the modern battlefield, it may be necessary to have fuel delivered by commercial carrier directly to the forward units. In addition, much greater emphasis is placed on the use of "fuels of convenience" (captured enemy stocks, fuel from disabled or destroyed vehicles, abandoned civilian sources, and on-the-spot commercial procurement). Due to the multitude of sources, various transportation contracts, and a lack of control, this fuel may be of questionable quality. During Operations Desert Shield/Storm, the Army's petroleum laboratories were unable to provide adequate the timely support on the expanded battlefield as they were deployed. Increased distances between using units and servicing laboratories, a lack of modern automated test equipment, and the absence of automated data processing systems all contributed to this shortfall.

b. Threat Analysis. The PQA will not counter any known threat; however, it may be a target of opportunity for threat forces and will be vulnerable to the entire spectrum of threat attack means to include sabotage by enemy controlled agents, terrorists, and special

operations forces; direct attack by combat units to include ground, airborne, and helicopter units; indirect fires to include artillery, rockets, missiles, and aerial attacks; and nuclear, biological, and chemical weapon systems.

c. Timing and Priority. This operational capability need is required before fiscal year 2000. It will support emerging Army operations doctrine as well as the Army's mission of providing inland distribution of petroleum to all services. It is within the top 50 percent of all operational capability needs in the U.S. Army Quartermaster Corps mission area.

3. **Nonmaterial Alternatives.** There are no changes in doctrine, training, leader development, organization, or personnel that would provide a mobile, in-depth, and rapid capability to analyze petroleum products throughout the entire battlefield utilizing current equipment.

4. **Potential Materiel Alternatives.** Develop a set of instruments that allow automated on-site analysis of petroleum products. Emerging technologies such as (but not limited to) near infrared (IR) spectroscopy, fourier transform IR spectroscopy, inductively coupled plasma spectroscopy, and gas chromatography may be used to accomplish this. The added capabilities could benefit interservice, allied operations, as testing support provided on an area basis can be applicable to all services in a theater of operations. Coordination with joint and allied services should be undertaken as appropriate.

5. **System Constraints.** The PQA must accommodate (within the required accuracy and precision) all tests necessary to determine fuel quality pertaining to acceptability. the likely maximum number of fuel samples analyzed in a 24 hour period and the maximum amount of time required to complete the testing and analysis of each fuel sample are to be determined. the PQA will be operated and maintained by existing Petroleum (career field 77) personnel. A decrease in authorizations for 77L personnel is anticipated. Institutional training will be incorporated into the Petroleum Laboratory Specialist Course taught by the U.S. Army Quartermaster Center and School. The equipment comprising the system must allow for transporting on the operation from a highly mobile, wheeled vehicle. Repair parts and tools required to perform operator maintenance must be provided with and contained within the system and be supportable within the current Army logistics system. Operators must be able to sustain operations during low light and hot, basic, and cold climatic categories. When not in use and properly stowed away, the PQA must be capable of surviving biological and chemical conditions. The system will utilize, to the maximum extent possible, internationally recognized standards of measurement and reporting to facilitate interoperability with allied services. The PQA and its packaging shall meet Army criteria for human factors. The PQA will not present and unnecessary health or safety risks to the user and will include appropriate laboratory safety equipment an personal protective clothing and equipment. The PQA will seek to reduce the level of mental and physical fatigue experienced by operators of predecessor systems. It will seek to minimize the damage caused by small arms fire and the resulting damage to operators. Deductibility of the PQA will be less than current system. The PQA will be as environmentally acceptable as is feasible.

6. **Joint Potential Designator.** The recommended Joint Potential Designator is Independent.

Appendix B Operational Requirements Document for Petroleum Quality Analysis (PQA)

OPERATIONAL REQUIREMENTS DOCUMENT
FOR
PETROLEUM QUALITY ANALYSIS SYSTEM (PQAS)

1. General Description of Operational Capability.

a. Overall Mission Area. The PQAS will enhance a petroleum unit's capability to receive, store, and issue fuel from a multitude of sources, to include both commercial and captured enemy stocks throughout the theater of operations (TO). It will be capable of deployment forward of forward support battalions (FSBs), conducting operations in hot, basic, and cold climatic conditions and worldwide deployment.

b. Type of System Proposed. The PQAS will be capable of performing testing in accordance with (IAW) Military Handbook 200 (MIL HDBK 200), Military Standardization Handbook, Quality Surveillance Handbook for Fuels, Lubricants, and Related Products, on all common military fuels (i.e., diesel fuels, motor gasoline, and jet propellants). Testing will be accomplished using standards, methods, and test devices approved for use by MIL HDBK 200. Testing will focus on a fuel's intended use at the customer level IAW MIL HDBK 200. When fuel is determined to be in a condition that prohibits or restricts its use, the PQAS will suggest corrective measures to bring the fuel within useful limits. The PQAS will be transportable on all aviation and ground assets that are designed to carry cargo. The PQAS will be deployed and operated on a High Mobility, Multipurpose, Wheeled Vehicle (HMMWV) or similar vehicle capable of movement within and forward of the FSB's area of operations. The PQAS will operate under day, night, and blackout conditions in hot, basic, and cold climatic conditions. It will be capable of self-sustained operations for a minimum of 30 days and will be supportable with expendable supplies and modular repair parts at the owning unit level.

c. Operational Concept. Current and evolving doctrine dictates the need for a highly mobile testing capability with communications capabilities equipped for independent operations throughout the theater. The equipment must be self-diagnostic and self-calibrating to minimize training time. The equipment must be capable of determining corrective actions to bring fuel within useful limits to enhance response times and to eliminate human error. The PQAS will meet this need through the use of emerging fuel testing technologies combined with computer data bases used for analysis of test results and the recommendation of fuel usage or disposition. Additionally, communications devices will allow test results to be transmitted to units as required and to maintain communications, command, and control over PQAS within the theater.

(1) Wartime Mission Profile (MP). The PQAS will be operational from the Communications Zone (COMMZ) to locations forward of the FSB. In the COMMZ, its mission will consist of testing fuels received from the Defense Fuel Supply Center and bulk

purchases from refineries, depots, and other sources as required. In the area of the main support battalion and FSB its mission will consist of testing fuels received through normal supply channels, locally procured from civil sources (i.e., gas stations, local vendors, etc.) and captured enemy stocks. it will be maneuverable insofar as it can deploy with the FSB as it relocates throughout the battle area.

(2) *Peacetime MP.* The PQAS will support field training exercises deployed and operating as they do under the wartime MP. Additionally, the PQAS will perform correlation testing for military activities and installations and will support various civilian agencies as ordered by the Department of Defense (DOD) and the U.S. Army.

d. Support Concept. The PQAS will have the potential to be fielded as a replacement for all existing field laboratories. The replacement value (i.e., 1:1, 2:1.5, 2:1, etc.) is to be determined and may vary with the assumed mission. It has not been determined if any units not currently equipped with petroleum laboratories will receive the PQAS. The basic support concept for the PQAS will not differ from those currently in effect for field petroleum laboratories except for the following:

(1) The petroleum test equipment within the PQAS will be self-diagnostic, self-calibrating, and both user and equipment fault tolerant. To the maximum degree possible, it will have embedded training in its software.

(2) Operator maintenance for the PQAS will consist of replacing defective equipment and parts modularly. Modules will be repaired at the depot and manufacturer levels as required.

e. Mission Need Statement (MNS) Summary. The MNS for a PQA capability was approved by Headquarters, Department of the Army on 6 Oct 93. It will resolve a deficiency identified in the Army Modernization Plan, Annex J, January 1993, as well as in the Quartermaster Functional Area Assessment, April 1993. The PQAS will enhance a maneuver unit's capabilities to maintain momentum and maneuver freedom with fuels from a multitude of sources including both friendly and unfriendly sources. Use of emerging fuel testing technologies, data processing and transmission, and voice communications will enable the PQAS to respond to a unit's fuel testing needs in minutes rather than hours or days. The use of advanced technology may result in a reduction of personnel required to perform the mission.

2. **Threat.** The PQA does not counter a specific threat. It will allow the confident use of both captured enemy fuels and fuels from suspect sources. PQA will be a target of opportunity for threat forces and will be vulnerable to the entire spectrum of threat attack means to include sabotage by enemy controlled agents, terrorists, and special operations forces; direct attack by combat units to include ground, airborne, and helicopter units; indirect fire to include artillery, rocket, missile, and aerial attacks; and biological and chemical weapons systems.

3. **Shortcomings of Existing Systems.** The use of current equipment in today's field laboratories results in a six hour-plus sample processing time under ideal conditions. This compares to about one hour using current automated equipment and methods utilizing emerging technology. Current petroleum field laboratories require external transportation to

relocate and are not designed to move as frequently as supported units. When compared to existing and emerging technology, current petroleum field laboratories are manpower intensive. Current laboratories lack automated sample analysis, automated data-processing, and communications. Automated equipment decreases the likelihood of human error. Lacking a communications capability hampers the response to a user's testing and fuel needs.

4. Capabilities Required.

a. System Performance. The PQAS must:

(1) Operate in both war and peacetime conditions under hot, basic, and cold climatic conditions and in all geographical locations.

(2) Perform 15 required, 30 desired, bulk fuel full tests for the appropriate mission level as prescribed in MIL HDBK 200 on samples representing multiple military fuels.

(3) Perform testing on each test device simultaneously with one sample or with multiple samples at one per device.

(4) Be self-contained and operate for a minimum of 30 days at a minimum of 15 samples per day without resupply of expendable supplies with the exception of those expendable supplies found commonly throughout the theater (e.g., water and fuel).

(5) Be ruggedized insofar as it will be operable on a vehicle with adequate mobility to move forward of the FSB under cross-country conditions.

b. Logistics and Readiness. The PQAS will:

(1) Use testing methods recognized and approved by MIL HDBK 200.

(2) Operate 16 hours per day required, 20 hours per day desired.

(3) Be operated by two soldiers required, one soldier desired, in Military Occupational Specialty (MOS) 77L.

(4) Require no more than a three Kilowatt generator to operate when not mounted on a vehicle. When installed on a vehicle, the PQAS will operate using the vehicles electrical system. It will have a battery that will allow one full test cycle to be performed in the event of a power failure.

(5) Have equipment that is self-diagnostic, self-calibrating, and fault tolerant to both equipment and operator errors.

(6) Have preventive maintenance checks and services (PMCS) that will take no more than 20 minutes before operation and 10 minutes after operation. During operation PMCS will not adversely affect test times.

(7) Be fully operational within 30 minutes of arrival on station and deployable 20 minutes after completion of sample processing.

(8) Be transportable both internally and externally by all aviation and ground assets having a cargo mission and capabilities. The PQAS will be transported by UH-60 helicopter when off of the HMMWV.

(9) Have reliability requirements of 160 hours mean time between essential function failure and 310 hours mean time between system abort. The maintainability requirement for the PQAS is a total maintenance ratio of 0.07 maintenance manhours per operating hour, (unit, direct support (DS), and general support (GS)).

c. Critical System Characteristics. The PQAS must:

(1) Be operable, transportable, and maintainable by soldiers from the 5th through 95th percentiles of the target audience.

(2) Survive biological and chemical attack to the ability of the host vehicle when not in use. When not mounted in a vehicle, the PQAS will survive biological or chemical attack when properly stowed in its containers. The PQAS is not intended for use in a contaminated environment.

(3) Be resistant to electronic counter-measures.

(4) Not present any uncontrollable hazards to the operators, maintenance personnel, or the environment.

5. Integrated Logistics Support (ILS).

a. Maintenance Planning. Support objectives for initial and full operational capability at the organizational (operator) levels are PMCS, scheduled services, and the modular replacement of defective and broken assemblies and subassemblies. At intermediate DS and GS levels, the objectives are for repair and replacement of those items authorized on the host vehicle, communications system, and for items to be determined specific to the PQAS. Depot repair will consist of repairing or contracting for repair those modules replaced at the operator, DS, and GS levels.

b. Support Equipment. All unit level maintenance will be accomplished with common tools and tools in the general mechanic's Tool Kit. Any special tools, if needed, will be provided in the basic issue items of the PQAS in sufficient quantities to enable extended operations. The PMCS will not exceed 20 minutes before operation and 10 minutes after operation and will consist primarily of visual inspections and equipment self-diagnostic tests. During operation, the PMCS will consist of equipment self-diagnostic tests, observation and cleaning of equipment being used, and replacement of expendable supplies as they are used.

c. Human System Integration.

(1) Manpower. The PQAS must not require additional personnel at the unit level or throughout the theater.

(2) Personnel. The PQAS must not increase personnel requirements (physical and mental) for the target MOS and must not require a new MOS.

(3) Training.

(a) Introduction of the PQAS will require both institutional and unit (sustainment) training. Training will provide the individual skills necessary for efficient employment of the PQAS. New equipment training teams or new materiel introductory teams may be required for fielding of the PQAS.

(b) Institutional and unit (sustainment) training will be conducted with bugged modular replacements or with software capable of giving a predetermined error. Training aids may be used for high-cost and/or frequently damaged modular replacement maintenance training.

(c) Instructor and key personnel training for the PQAS will be required. Technical Manuals and all training products to include operator and maintainer task lists, program of instruction, lesson plans, and student hand-outs, will be concurrently developed and delivered in draft form prior to operational testing and fielding. Technical manuals, training products, bugged modular replacements, and installation instructions will be provided with the PQAS during initial fielding to support initial and unit (sustainment) training. Institutional training will be modified to support the PQAS.

(4) Human Factors Engineering. The PQAS will be maintained, supported, and operated by representative soldiers (5th to 95th percentile in the designated target audience) to prescribed performance standards. The PQAS will be capable of being transported by soldiers in mission-oriented protective posture gear at all levels and in cold weather overgarments.

(5) System Safety. The PQAS must not introduce any uncontrolled safety hazards to personnel or equipment. Hazards which must be controlled include, but are not limited to: increased risk of fire and contamination from fuel; increased risk of fire and contamination from chemicals, solvents, and cleaning agents associated with operating the PQAS; hazardous material disposal, environmental contamination; and exposure to fumes and vapors from the aforementioned products. Health hazards must be eliminated or controlled to an acceptable level.

d. Computer Resources.

(1) The computer integrated within the PQAS must be compatible with the standard Army computer used at the time of fielding. It will be totally integrated with PQAS testing devices. It will contain datafax/modem capabilities compatible with current and planned future Army datafax/modems.

(2) It will have the capability to store at least one year of test data.

(3) It will contain all the software necessary to analyze data obtained from the testing instruments. It will contain in its data base the specifications and all other pertinent information for all currently used military fuels. It will recommend courses of action to correct fuel that is off specification. It will describe in general terms problems associated with the use of off specification fuel.

e. Other Logistics Considerations.

(1) To be fully operational from a vehicle, the electrical system and cargo space layout may have to be modified.

(2) The fielding strategy is to use the total package concept. Before fielding, all spare and repair parts must be available within the Army supply system.

(3) Long-term storage requirements will have to be determined.

(4) The ILS plan (ILSP) will be prepared by the materiel developer.

6 . Infrastructure Support and Interoperability.

a. Command, Control, Communications, and Intelligence. The PQAS will have communications devices to include a datafax/modem capability to allow transmission of test data and instructions to the fuel-using unit. This equipment will be used to maintain communications with PQAS-owning units, to verbally requisition expendable supplies and replacement parts, and to notify division, corps, and theater fuel managers of any fuel-related problems. Additionally, the communications equipment will be used as an alternative communications device for forwarding various petroleum reports and requisitions.

b. Transportation and Basing.

(1) Movement to and within a To will be by all transportation systems having a cargo mission, including marine, air, and ground. The PQAS must be capable of installation and transportation in and operation from a HMMWV.

(2) Introduction of the PQAS will not require any changes to basing or associated facilities.

c. Standardization, Interoperability, and Commonality.

(1) The PQAS will use accepted methods of testing as prescribed in MIL HDBK 200, applicable interservice agreements, North Atlantic Treaty Organization Standardization Agreements (NATO STANAG), and memoranda of understanding for the appropriate level of testing.

(2) Due to the application of emerging technology, no other service or allied nation currently utilizes the methodology expected to be employed by the PQAS. With the advantages achieved with the fielding of this system over current technology, it is expected that the PQAS will have DOD-wide application and will be of interest to our allies.

7. **Force Structure.** The PQAS will be used by combat service support units throughout the Active and Reserve Components.

8. Schedule Considerations.

a. ***Initial Operational Capability (IOC).*** An objective date for IOC is to be determined. The IOC will be obtained when the following criteria are met:

(1) Initial first unit equipped (FUE) and training base required devices are on hand, safe to operate and maintain, and perform their intended mission.

(2) The FUE and training base sets are fully logistically supportable, i.e., spare and repair parts are in the wholesale and retail supply system; government-approved training, field, and maintenance manuals are on hand and operator and maintainer training have been successfully initiated and completed.

(3) An initial operational test is completed in the intended mission environment(s) to evaluate the completeness of achieving paragraphs 8.a.(l) and 8.a.(2).

b. ***Full Operational Capability (FOC).*** The FOC occurs when all units identified to receive the PQAS achieve the criteria specified in paragraphs 8.a.(l) through 8.a.(3).

ANNEX A
RATIONALE

The following rationale corresponds to subparagraphs of paragraph 4, Capabilities Required:

4. Capabilities Required.

a. System Performance. The PQAS must:

(1) Operate in both war and peacetime conditions under hot, basic, and cold climatic conditions and in all geographical locations.

Rationale. The PQAS must be capable of operating in all environments where its customers are located. It must be capable of operating under peacetime constraints in order to establish and maintain a cadre of trained operators.

(2) Perform 15 required, 30 desired, bulk fuel full tests for the appropriate mission level as prescribed in MIL HDBK 200 on samples representing multiple military fuels.

Rationale. A single system must be capable of meeting the needs of a majority of the customers within a given area.

(3) Perform testing on each test device simultaneously with one sample or with multiple samples at one per device.

Rationale. This allows the operator to perform similar steps at one time and allows for speedier operation.

(4) Be self-contained and operate for a minimum of 30 days at a minimum of 15 samples per day without resupply of expendable supplies with the exception of those expendable supplies found commonly throughout the theater (e.g., water and fuel).

Rationale. The PQAS must be capable of directly supporting customers' needs which are not capable of logistically supporting PQAS equipment.

(5) Be ruggedized insofar as it will be operable on a vehicle with adequate mobility to move forward of the FSB under cross-country conditions.

Rationale. The PQAS must be capable of moving forward to test fuels of convenience, allowing them to be used as quickly as possible to reduce logistical resupply.

b. Logistics and Readiness.

(1) Use testing methods recognized and approved by MIL HDBK 200.

Rationale. The DOD has accepted American Society for Testing and Materiels as the standard for test procedures.

(2) Operate 16 hours per day required, 20 hours per day desired.

Rationale. The PQAS must be capable of operating extended hours to meet battlefield needs.

(3) Be operated by two soldiers required, one soldier desired in Military Occupational Specialty (MOS) 77L.

Rationale. In order to maintain a quick response to a changing environment, a minimum of personnel are required for operation and movement of the PQAS.

(4) Require no more than a three kilowatt generator to operate when not mounted on a vehicle. When installed on a Vehicle, the PQAS will operate using the vehicles electrical system. It will have a battery that will allow of one full test cycle to be performed in the event of a power failure.

Rationale. Operation from a variety of electrical sources is required in order to facilitate mobility and self-containment.

(5) Have equipment that is self-diagnostic, self-calibrating, and fault tolerant to both equipment and operator errors.

Rationale. Self-diagnostic, self-calibrating, fault tolerant equipment minimizes preventive maintenance checks and services (PMCS) time and allows the operator to concentrate on other tasks while testing is performed.

(6) Have PMCS that take no more than 20 minutes before operation and 10 minutes after operation. During operation the PMCS will not adversely affect test times.

Rationale. The PMCS time must be minimized to enhance the overall, quick response time of a mobile laboratory.

(7) Be fully operational within 30 minutes of arrival on station and deployable 20 minutes after completion of sample processing.

Rationale. Set-up and tear-down times must be minimized to enhance the overall, quick response time of the PQAS.

(8) Be transportable both internally and externally by all aviation and ground assets having a cargo mission and capabilities. The PQAS will be transported by UH-60 helicopter when off of the HMMWV.

Rationale. In order to be fully mobile, the PQAS will need to be capable of utilizing available transportation.

(9) Have reliability requirements of 160 hours mean time between essential function failure and 310 hours mean time between system abort. The maintainability requirement for the PQAS is a total maintenance ratio of 0.07 maintenance manhours per operating hour, (unit, direct support (DS), and general support (GS)).

Rationale. See Annex B.

c. ***Critical System Characteristics.*** The PQAS must:

(1) Be operable, transportable, and maintainable by soldiers from the 5th through 95th percentiles of the target audience.

Rationale. The PQAS must be operable, transportable, and maintainable by the largest audience feasible.

(2) Survive biological and chemical attack to the ability of the host vehicle when not in use. When not mounted in a vehicle, the PQAS will survive biological or chemical attack when properly stowed in its containers. The PQAS is not intended for use in a contaminated environment.

Rationale. The PQAS must be a survivable system under all conditions.

(3) Be resistant to electronic counter measures.

Rationale. The PQAS must be survivable on the modern battle-field.

(4) Not present any uncontrollable hazards to operators, maintenance personnel, or the environment.

Rationale. The PQAS must be inherently safe in order to establish personal confidence in the system.

ANNEX B

OPERATIONAL MODE SUMMARY (OMS) AND MP

1. **Operational Concept.** operating conditions for the PQAS will be in hot, basic, and cold climatic categories as specified in Army Regulation (AR) 70-38. It will be used in all geographical locations. PQAS will be used during day and night, to include blackout conditions, across the operational continuum (to include electronic countermeasures, smoke, and dust). PQAS will perform fuel testing throughout the theater to include forward of the FSB. PQAS will be capable of being airlifted over terrain incapable of transit by ground vehicle and being operational within 30 minutes of the aircraft landing. The anticipated use of PQAS is in both developed and non-developed theaters.

2. **Threat Matrix.**

Table l. Threat Matrix

Threat	Indirect	Strike	Direct Strike
Artillery		X	
Rockets		X	
Bombs		X	
Nuclear		X	
Biological			X
Chemical		X	
Sabotage		X	
Raids	X		
Other theater area attack weapons	X		

3. **Wartime OMS/MP.** The PQAS is required to perform 15 bulk fuel full tests for the appropriate mission level (as prescribed in MIL HDBK 200) per day on samples representing multiple military fuels. The number of tests required per day will be reduced on movement days as shown in Table 2. The PQAS fuel test involves placing the fuel sample in the test device, automatic performance of the test; output of the results and recommendations to the video display and/or printer; storage of the test results and recommendations; and, as required, transmission of results and recommendations over communication links. The PQAS is required to operate for 30 days at a minimum of 15 samples per day under this OMS/MP without resupply of expendable supplies with the exception of those expendable supplies found commonly throughout the theater (e.g., water, fuel, etc.). The PQAS will move between sites on approximately 5 of every 7 operating days, with 4 short move days (50-100 miles) and 1 long move day (400 miles).

   The PMCS are performed at the beginning of the mission day and at the end of the mission day. Additionally, the PMCS are performed simultaneously with set up and tear down of the PQAS. Table 2 depicts a one-week mission for the PQAS. Note that the PMCS addressed in

this OMS/MP apply only to PQAS devices and not to the transport vehicle or any shelter that is used.

Table 2. Wartime OMS/MP

Event	SHORT MOVE DAY (4/wk)		LONG MOVE DAY (1/wk)		NO MOVE DAY (2/wk)	
	No. of Events	Total Time	No. of Events	Total Time	No.of Events	Total Time
Fuel Test* Output* Store Results* Transmit*	9 9 9 9	11.25 hrs	3 3 3 3	3.75 hrs	15 15 15 15	16 hrs
Set up w/PMCS	1	30 min	2@ .5 hr each	1 hr	0	N/A
Tear down W/PMCS	1	20 min	2@ 20 min each	40 mi	0	N/A
Move	1	3.4 hr	2@ 5 hr each	10 hrs	0	N/A
Before-Operation PMCS	1	20 min	1	20 min	1	20 min
After-Operation PMCS	1	10 min	1	10 min	1	10 min

**Times over-lap*

A typical week of operations IAW Table 2 would resemble the following:

Day 1. No move day. Perform before-operations PMCS, perform 15 fuel tests, perform after operations PMCS.

Day 2. Short move day. Perform before-operations PMCS, perform five fuel tests, tear down system (including after operations PMCS), move system to new site, set up system (including before-operations PMCS), perform four fuel tests, perform after-operations PMCS.

Day 3. Short move day. Perform before-operations PMCS, perform five fuel tests, tear down system (including after operations PMCS), move system to new site, set up system (including before-operations PMCS), perform four fuel tests, perform after-operations PMCS.

Day 4. Long move day. Perform before-operations PMCS, perform one fuel test, tear down system (including after operations PMCS), move system to new site, set up system (including before-operations PMCS), perform one fuel test, tear down system (including after-operations PMCS), move system to new site, set up system (including before operations PMCS), perform one fuel test, perform after-operations PMCS.

Day 5. No move day. Perform before-operations PMCS, perform 15 fuel tests, perform after-operations PMCS.

Day 6. Short move day. Perform before-operations PMCS, perform five fuel tests, tear down system (including after-operations PMCS), move system to new site, set up system (including before-operations PMCS), perform four fuel tests, perform after-operations PMCS-

Day 7. Short move day. Perform before-operations PMCS, perform five fuel tests, tear down system (including afteroperations PMCS), move system to new site, set up system (including before-operations PMCS), perform four fuel tests, perform after-operations PMCS.

4. **Peacetime OMS/MP.** The PQAS will support field training exercises deployed and operating in the same manner as prescribed in the wartime OMS/MP. Additionally, the PQAS will perform correlation testing for military activities and installations and will support various civilian agencies as ordered by the DOD and U.S. Army. The PQAS assigned to U.S. Army Reserve and National Guard component units will operate under the wartime OMS/MP 49 days per year. The PQAS assigned to Fort Lee, Virginia, will be used as a training base and will operate 240 days per year.

5. **Environmental Conditions.** The environmental conditions in which the PQAS will be operated are shown in Table 3.

Table 3. Environmental Conditions

Climatic Design Types (AR 70-38)	Usage %
Hot	20
Basic	70
Cold	10

6. **Movement Terrain.** The movement terrain expected to be encountered by the PQAS is shown in Table 4.

Table 4. Movement Terrain

Terrain	Usage %
Primary Roads (Long Move)	5%
Secondary Roads (Short Move)	55%
Cross Country (Short Move)	40%

ANNEX C

COORDINATION

ORGANIZATION	CONCUR	COMMENTS
HQDA	X	0
BRDEC	X	0
ATCOM	X	0
FORSCOM	X	0
CASCOM	X	0
USACAC	X	0
USAPC	X	0
DFSC	X	0
USAOEC	X	0
USAHEL	X	0
USAIS	X	0
USAOC&S	X	0
USAPIC	X	0
AMC	X	0
USATSCH	X	0
USAALS	X	0
USAARMS	X	0
USAAVNS	X	0

ANNEX D

FUNDING IMPLICATIONS

The following is the U.S. Army Tank-Automotive Command, Mobility Technology Center-Belvoir, Cost Analysis Division, validated cost estimate for the PQAS in constant FY94 dollars (millions).

	FY94	FY95	FY96	FY97
Research and Development	0.283	1.231	1.708	1.327
Production	0	0	0	0
Fielding	0	0	0	0
Sustainment	0	0	0	0
Total Requirement	0.283	1.231	1.708	1.327
Acquisition Quantity	0	0	0	0

	FY98	FY99	FYOO	FY01-15
Research and Development	1.379	1.470	0.100	0
Production	0	0	0	9.979
Fielding	0	0	0.100	0.200
Sustainment	0	0	0	16.861
Total Requirement	1.379	1.470	0.200	27.040
Acquisition Quantity	2	0	0	17

Total Program Cost: 34.638

Total Acquisition Quantity: 19

Appendix C List of Fuel Samples

Table 9. List of Fuel Samples

SAMPLE NUMBER	SAMPLE ORIGIN	FUEL TYPE	TEST DATA
93-POSF-2959	WPAFB BLDG 490	JET A	YES
92-POSF-2928	WPAFB BLDG 490	JET A	YES
92-POSF-2926	WPAFB BLDG 490	JET A	YES
93-POSF-2747	WPAFB BLDG 490	JET A	YES
92-POSF-2930	WPAFB BLDG 490	JET A	YES
91-POSF-2827	WPAFB BLDG 490	JET A	YES
92-POSF-2922	WPAFB BLDG 490	JET A	YES
93-F-173	WPAFB KELLY DET	JET A	YES
93-F-142	WPAFB KELLY DET	JET A	YES
93-F-304	WPAFB KELLY DET	JET A	YES
93-F-280	WPAFB KELLY DET	JET A	YES
93-F-560	WPAFB KELLY DET	JET A	YES
93-F-665	WPAFB KELLY DET	JET A	YES
93-F-444	WPAFB KELLY DET	JET A	YES
92-POSF-2931	WPAFB BLDG 490	JET A-1	YES
92-POSF-2936	WPAFB BLDG 490	JP-8	YES
AL-20011-F	BFLRF (SwRI)	JP-8	NO
AL-20335-F	BFLRF (SwRI)	JP-8	NO
AL-19850-F	BFLRF (SwRI)	JP-8	NO
AL-20123-F	BFLRF (SwRI)	JP-8	NO
AL-20336-F	BFLRF (SwRI)	JP-8	NO
AL-19903-F	BFLRF (SwRI)	JP-8	NO
93-F-351	WPAFB KELLY DET	JP-8	NO
92-POSF-2934	WPAFB BLDG 490	JP-8	YES
93-POSF-2963	WPAFB BLDG 490	JP-5	NO
91-POSF-2817	WPAFB BLDG 490	JP-5	YES
93-F-284	WPAFB KELLY DET	JP-5	YES
93-F-311	WPAFB KELLY DET	JP-5	YES
93-F-312	WPAFB KELLY DET	JP-5	YES
93-F-310	WPAFB KELLY DET	JP-5	YES
93-F-313	WPAFB KELLY DET	JP-5	YES
93-F-374	WPAFB KELLY DET	JP-5	YES
93-F-668	WPAFB KELLY DET	JP-5	YES
93-L-100	WPAFB KELLY DET	DF-2	YES
AL-20221-F	BFLRF (SwRI)	DF-2	YES
AL-19915-F	BFLRF (SwRI)	DF-2	YES
91-POSF-2818	WPAFB BLDG 490	JP-7	NO
91-POSF-2799	WPAFB BLDG 490	JP-TS	NO
AL-20027-F	BFLRF (SwRI)	TURBINE	NO

Table 9. List of Fuel Samples (continued)

SAMPLE NUMBER	SAMPLE ORIGIN	FUEL TYPE	TEST DATA
93-F-625	WPAFB KELLY DET	JP-4	YES
93-F-653	WPAFB KELLY DET	JP-4	YES
93-F-586	WPAFB KELLY DET	JP-4	YES
93-F-640	WPAFB KELLY DET	JP-4	YES
93-F-591	WPAFB KELLY DET	JP-4	YES
93-F-624	WPAFB KELLY DET	JP-4	NO
93-F-152	WPAFB KELLY DET	JP-4	YES
93-F-412	WPAFB KELLY DET	JP-4	YES
93-F-347	WPAFB KELLY DET	JP-4	YES
93-F-402	WPAFB KELLY DET	JP-4	YES
93-F-233	WPAFB KELLY DET	JP-4	YES
DEJESS	WPAFB BLDG 490	JP-4	NO
93-F-201	WPAFB KELLY DET	AVGAS	YES
93-F-295	WPAFB KELLY DET	AVGAS	YES
93-F-289	WPAFB KELLY DET	AVGAS	YES
93-F-290	WPAFB KELLY DET	AVGAS	YES
93-F-279	WPAFB KELLY DET	AVGAS	YES
93-F-644	WPAFB KELLY DET	AVGAS	YES
93-F-643	WPAFB KELLY DET	AVGAS	YES
93-F-609	WPAFB KELLY DET	AVGAS	YES
93-F-539	WPAFB KELLY DET	AVGAS	YES
93-F-610	WPAFB KELLY DET	AVGAS	YES
93-F-338	WPAFB KELLY DET	AVGAS	YES
93-F-551	WPAFB KELLY DET	AVGAS	YES
93-F-326	WPAFB KELLY DET	MOGAS	YES
93-F-307	WPAFB KELLY DET	MOGAS	YES
93-F-339	WPAFB KELLY DET	MOGAS	YES
93-F-306	WPAFB KELLY DET	MOGAS	YES
93-F-464	WPAFB KELLY DET	MOGAS	YES
93-F-638	WPAFB KELLY DET	MOGAS	YES
93-F-449	WPAFB KELLY DET	MOGAS	YES

Appendix D Specification Test Data

Table 10. Specification Test Data

PROPERTY	93-POSF-2959	92-POSF-2928	92-POSF-2926	93-POSF-2747	92-POSF-2930
TAN, mg KOH/g	0.002	0.013	0.002	0.0	0.001
Aromatics, Vol %	20	19	22	19	19
Olefins, Vol %	N/A	N/A	N/A	N/A	N/A
Sulfur, Mass %	0.16	0.1	0.1	0.0	0.1
Mercaptan Sulfur, wt %	0.002	0.002	0.001	0.001	0.001
Hydrogen, Mass %	N/A	N/A	N/A	N/A	N/A
Distillation, °C					
IBP	N/A	N/A	N/A	N/A	N/A
10 % Pt	176	179	183	185	179
50 % Pt	199	205	213	193	207
90 % Pt	231	239	246	211	245
FBP	250	259	264	236	263
Residue, Vol %	N/A	1.2	1.1	0.9	1.3
Loss, Vol %	N/A	1.2	1.2	0.4	1.0
Gravity, °API	N/A	N/A	N/A	N/A	N/A
Density, Kg/m^3	792	806	811	808	796
Freezing Point, °C	-48	-48	-43	-60	-43
Flash Point, °C	48	51	43.9	60	50
Kinematic Viscosity, cSt					
@ -20°C	3.9	5	N/A	4	5
@ 40°C	N/A	N/A	N/A	N/A	N/A
Net Heat of Combustion, Mj/Kg	N/A	N/A	N/A	N/A	N/A
Existent Gum, mg/100mL	1.0	1.0	1.0	N/A	N/A
Particulate Matter, mg/L	N/A	0.1	0.1	0.8	N/A
FSII, Vol %	N/A	0.0	0.0	0.0	0.0
Vapor Pressure, Kpa	N/A	N/A	N/A	N/A	N/A
Lead, g/L	N/A	N/A	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	91-POSF-2827	92-POSF-2922	93-F-173	93-F-142	93-F-304
TAN, mg KOH/g	0.001	0.004	0.006	0.002	0.0
Aromatics, Vol %	19	19	20	18	14
Olefins, Vol %	N/A	N/A	N/A	N/A	N/A
Sulfur, Mass %	0.1	0.02	0.1	0.1	0.1
Mercaptan Sulfur, wt %	0.001	N/A	0.001	0.002	0.002
Hydrogen, Mass %	N/A	N/A	N/A	N/A	N/A
Distillation, °C					
IBP	N/A	185	N/A	N/A	N/A
10 % Pt	179	199	187	180	202
50 % Pt	207	215	214	209	232
90 % Pt	245	238	250	246	275
FBP	263	266	273	265	293
Residue, Vol %	1.3	1.0	1.2	1.1	1.4
Loss, Vol %	1.0	0.1	0.9	0.8	1.1
Gravity, °API	N/A	N/A	N/A	N/A	N/A
Density, Kg/m^3	807	806	812	810	812
Freezing Point, °C	-43	-46	-47	-45	-44
Flash Point, °C	50	44	52	47	44
Kinematic Viscosity, cSt					
@ -20°C	5	5.5	6	5	5.8
@ 40°C	N/A	N/A	N/A	N/A	N/A
Net Heat of Combustion, Mj/Kg	N/A	N/A	N/A	N/A	N/A
Existent Gum, mg/100mL	N/A	1.0	1.0	1.0	1.2
Particulate Matter, mg/L	N/A	N/A	0.2	0.4	2.8
FSII, Vol %	0.0	N/A	0.0	0.11	0.12
Vapor Pressure, Kpa	N/A	N/A	N/A	N/A	N/A
Lead, g/L	N/A	N/A	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	93-F-280	92-POSF-2931	92-POSF-2936	AL-20011-F	AL-20335-F
TAN, mg KOH/g	N/A	0.001	0.014	N/A	N/A
Aromatics, Vol %	16	19	18	N/A	N/A
Olefins, Vol %	N/A	N/A	N/A	N/A	N/A
Sulfur, Mass %	N/A	0.1	0.1	N/A	N/A
Mercaptan Sulfur, wt %	N/A	0.001	0.001	N/A	N/A
Hydrogen, Mass %	N/A	N/A	N/A	N/A	N/A
Distillation, °C					
IBP	N/A	N/A	132	N/A	N/A
10 % Pt	192	179	175	N/A	N/A
50 % Pt	215	207	214	N/A	N/A
90 % Pt	246	245	248	N/A	N/A
FBP	266	263	279	N/A	N/A
Residue, Vol %	1.0	1.3	N/A	N/A	N/A
Loss, Vol %	0.8	1.0	N/A	N/A	N/A
Gravity, °API	N/A	N/A	N/A	N/A	N/A
Density, Kg/m^3	811	798	807	806	803
Freezing Point, °C	-49	-43	N/A	N/A	N/A
Flash Point, °C	56	50	60	N/A	N/A
Kinematic Viscosity, cSt					
@ -20°C	N/A	5	5.5	N/A	N/A
@ 40°C	N/A	N/A	N/A	N/A	N/A
Net Heat of Combustion, Mj/Kg	N/A	N/A	N/A	N/A	N/A
Existent Gum, mg/100mL	1	N/A	1.8	N/A	N/A
Particulate Matter, mg/L	0.8	N/A	N/A	N/A	N/A
FSII, Vol %	0.08	0.0	0.12	N/A	N/A
Vapor Pressure, Kpa	N/A	N/A	N/A	N/A	N/A
Lead, g/L	N/A	N/A	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	AL-19850-F	AL-20123-F	AL-20336-F	AL-19903-F	93-F-351
TAN, mg KOH/g	N/A	N/A	N/A	N/A	N/A
Aromatics, Vol %	N/A	N/A	N/A	N/A	N/A
Olefins, Vol %	N/A	N/A	N/A	N/A	N/A
Sulfur, Mass %	N/A	N/A	N/A	N/A	N/A
Mercaptan Sulfur, wt %	N/A	N/A	N/A	N/A	N/A
Hydrogen, Mass %	N/A	N/A	N/A	N/A	N/A
Distillation, °C					
IBP	N/A	N/A	N/A	N/A	N/A
10 % Pt	N/A	N/A	N/A	N/A	N/A
50 % Pt	N/A	N/A	N/A	N/A	N/A
90 % Pt	N/A	N/A	N/A	N/A	N/A
FBP	N/A	N/A	N/A	N/A	N/A
Residue, Vol %	N/A	N/A	N/A	N/A	N/A
Loss, Vol %	N/A	N/A	N/A	N/A	N/A
Gravity, °API	N/A	N/A	N/A	N/A	N/A
Density, Kg/m^3	801	802	800	804	796
Freezing Point, °C	N/A	N/A	N/A	N/A	N/A
Flash Point, °C	N/A	N/A	N/A	N/A	N/A
Kinematic Viscosity, cSt					
@ -20°C	N/A	N/A	N/A	N/A	N/A
@ 40°C	N/A	N/A	N/A	N/A	N/A
Net Heat of Combustion, Mj/Kg	N/A	N/A	N/A	N/A	N/A
Existent Gum, mg/100mL	N/A	N/A	N/A	N/A	N/A
Particulate Matter, mg/L	N/A	N/A	N/A	N/A	N/A
FSII, Vol %	N/A	N/A	N/A	N/A	N/A
Vapor Pressure, Kpa	N/A	N/A	N/A	N/A	N/A
Lead, g/L	N/A	N/A	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	92-POSF-2934	93-POSF-2963	91-POSF-2817	93-F-284	93-F-311
TAN, mg KOH/g	0.043	N/A	N/A	N/A	N/A
Aromatics, Vol %	21	N/A	N/A	17	18
Olefins, Vol %	N/A	N/A	N/A	1.6	1.6
Sulfur, Mass %	0.1	N/A	N/A	0.08	N/A
Mercaptan Sulfur, wt %	0.0	N/A	N/A	N/A	N/A
Hydrogen, Mass %	N/A	N/A	N/A	N/A	N/A
Distillation, °C					
IBP	96	N/A	131	139	136
10 % Pt	151	N/A	180	172	172
50 % Pt	202	N/A	218	212	215
90 % Pt	249	N/A	253	245	250
FBP	270	N/A	281	273	282
Residue, Vol %	N/A	N/A	N/A	N/A	N/A
Loss, Vol %	N/A	N/A	N/A	N/A	N/A
Gravity, °API	N/A	N/A	N/A	N/A	N/A
Density, Kg/m^3	807	809	813	806	807
Freezing Point, °C	-52	N/A	N/A	N/A	-50
Flash Point, °C	39	N/A	N/A	62	61
Kinematic Viscosity, cSt					
@ -20°C	4.4	N/A	N/A	5.5	5.7
@ 40°C	N/A	N/A	N/A	N/A	N/A
Net Heat of Combustion, Mj/Kg	N/A	N/A	N/A	N/A	N/A
Existent Gum, mg/100mL	0.2	N/A	N/A	1.4	0.6
Particulate Matter, mg/L	0.5	N/A	N/A	0.6	0.6
FSII, Vol %	0.0	N/A	N/A	0.14	0.18
Vapor Pressure, Kpa	N/A	N/A	N/A	N/A	N/A
Lead, g/L	N/A	N/A	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	93-F-312	93-F-310	93-F-313	93-F-152	DEJESS
TAN, mg KOH/g	N/A	N/A	N/A	0.005	N/A
Aromatics, Vol %	18	18	18	9	N/A
Olefins, Vol %	1.6	1.2	1.3	1.2	N/A
Sulfur, Mass %	N/A	N/A	N/A	0.03	N/A
Mercaptan Sulfur, wt %	N/A	N/A	N/A	0.001	N/A
Hydrogen, Mass %	N/A	N/A	N/A	14.7	N/A
Distillation, °C					
IBP	136	135	134	-8	N/A
10 % Pt	172	171	171	87	N/A
50 % Pt	215	214	214	129	N/A
90 % Pt	250	249	250	224	N/A
FBP	282	282	282	281	N/A
Residue, Vol %	N/A	N/A	N/A	N/A	N/A
Loss, Vol %	N/A	N/A	N/A	N/A	N/A
Gravity, °API	N/A	N/A	N/A	N/A	N/A
Density, Kg/m^3	807	807	807	754	757
Freezing Point, °C	-50	-50	-50	-61	N/A
Flash Point, °C	61	60	60	N/A	N/A
Kinematic Viscosity, cSt					
@ -20°C	5.7	5.6	5.5	N/A	N/A
@ 40°C	N/A	N/A	N/A	N/A	N/A
Net Heat of Combustion, Mj/Kg	N/A	N/A	N/A	43.7	N/A
Existent Gum, mg/100mL	0.6	0.6	1.4	0.2	N/A
Particulate Matter, mg/L	0.6	0.3	0.3	0.4	N/A
FSII, Vol %	0.18	0.19	N/A	0.12	N/A
Vapor Pressure, Kpa	N/A	N/A	N/A	16	N/A
Lead, g/L	N/A	N/A	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	93-F-347	93-F-412	93-F-402	93-F-233	93-F-201
TAN, mg KOH/g	N/A	0.004	0.004	0.003	N/A
Aromatics, Vol %	8	12	15	15	N/A
Olefins, Vol %	1.8	2.3	0.5	0.6	N/A
Sulfur, Mass %	0.01	0.01	0.03	0	0.001
Mercaptan Sulfur, wt %	N/A	0	0.001	N/A	N/A
Hydrogen, Mass %	14.6	14.5	14.3	14.1	N/A
Distillation, °C					
IBP	7	19	23	N/A	N/A
10 % Pt	83	73	75	N/A	74
50 % Pt	125	125	124	121	102
90 % Pt	231	231	236	164	108
FBP	291	291	293	209	138
Residue, Vol %	N/A	N/A	N/A	N/A	1
Loss, Vol %	N/A	N/A	N/A	N/A	1.2
Gravity, °API	N/A	N/A	N/A	N/A	N/A
Density, Kg/m^3	754	754	758	755	700
Freezing Point, °C	N/A	-61	-61	-80	-45
Flash Point, °C	N/A	N/A	N/A	N/A	N/A
Kinematic Viscosity, cSt					
@ -20°C	N/A	N/A	N/A	N/A	N/A
@ 40°C	N/A	N/A	N/A	N/A	N/A
Net Heat of Combustion, Mj/Kg	43.7	43.6	43.5	43.4	N/A
Existent Gum, mg/100mL	3.4	0.3	2	1.2	N/A
Particulate Matter, mg/L	0.4	0.2	7.7	0.3	N/A
FSII, Vol %	0.13	0	0.12	0.12	N/A
Vapor Pressure, Kpa	12.5	18.2	17.5	14	5.7
Lead, g/L	N/A	N/A	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	93-F-295	93-F-289	93-F-290	93-F-279	93-F-326
TAN, mg KOH/g	N/A	N/A	N/A	N/A	N/A
Aromatics, Vol %	N/A	N/A	N/A	N/A	N/A
Olefins, Vol %	N/A	N/A	N/A	N/A	N/A
Sulfur, Mass %	N/A	N/A	N/A	N/A	N/A
Mercaptan Sulfur, wt %	N/A	N/A	N/A	N/A	N/A
Hydrogen, Mass %	N/A	N/A	N/A	N/A	N/A
Distillation, °C					
IBP	N/A	N/A	N/A	N/A	31
10 % Pt	69	65	42	64	57
50 % Pt	99	100	102	99	99
90 % Pt	107	106	116	113	182
FBP	121	118	149	149	218
Residue, Vol %	1.3	0.9	1.5	1.5	1.5
Loss, Vol %	1.1	1.3	0.6	1.3	0.0
Gravity, °API	N/A	N/A	N/A	64.8	60.5
Density, Kg/m^3	709	705	718	723	729
Freezing Point, °C	-100	-99	-99	<-80	N/A
Flash Point, °C	N/A	N/A	N/A	N/A	N/A
Kinematic Viscosity, cSt					
@ -20°C	N/A	N/A	N/A	N/A	N/A
@ 40°C	N/A	N/A	N/A	N/A	N/A
Net Heat of Combustion, Mj/Kg	N/A	N/A	N/A	N/A	N/A
Existent Gum, mg/100mL	N/A	N/A	N/A	N/A	N/A
Particulate Matter, mg/L	N/A	N/A	N/A	N/A	N/A
FSII, Vol %	N/A	N/A	N/A	N/A	N/A
Vapor Pressure, Kpa	5.5	5.5	5.6	6.2	8.0
Lead, g/L	N/A	N/A	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	93-F-307	93-F-339	93-F-306	93-L-100	AL20221-F
TAN, mg KOH/g	N/A	N/A	N/A	N/A	N/A
Aromatics, Vol %	N/A	N/A	N/A	N/A	N/A
Olefins, Vol %	N/A	N/A	N/A	N/A	N/A
Sulfur, Mass %	N/A	N/A	N/A	0.15	N/A
Mercaptan Sulfur, wt %	N/A	N/A	N/A	N/A	N/A
Hydrogen, Mass %	N/A	N/A	N/A	N/A	N/A
Distillation, °C					
IBP	N/A	54	N/A	N/A	N/A
10 % Pt	54	100	49	N/A	N/A
50 % Pt	97	136	74	262	N/A
90 % Pt	163	140	156	315	N/A
FBP	N/A	169	201	347	N/A
Residue, Vol %	1.4	1.3	N/A	1	N/A
Loss, Vol %	N/A	0.2	N/A	N/A	N/A
Gravity, °API	N/A	37.1	N/A	N/A	N/A
Density, Kg/m^3	741	834	741	847	861
Freezing Point, °C	N/A	N/A	N/A	N/A	N/A
Flash Point, °C	N/A	N/A	N/A	49	N/A
Kinematic Viscosity, cSt					
@ -20°C	N/A	N/A	N/A	N/A	N/A
@ 40°C	N/A	N/A	N/A	2.4	N/A
Net Heat of Combustion, Mj/Kg	N/A	N/A	N/A	N/A	N/A
Existent Gum, mg/100mL	N/A	N/A	N/A	N/A	N/A
Particulate Matter, mg/L	N/A	N/A	N/A	1	N/A
FSII, Vol %	N/A	N/A	N/A	N/A	N/A
Vapor Pressure, Kpa	7.81	2.90	N/A	N/A	N/A
Lead, g/L	N/A	N/A	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	AL-19915-F	93-F-560	93-F-668	93-F-44	93-F-665
TAN, mg KOH/g	N/A	0.0	0.003	0.006	0.001
Aromatics, Vol %	N/A	16	21	16	17
Olefins, Vol %	N/A	N/A	2.9	N/A	N/A
Sulfur, Mass %	N/A	0.06	0.02	0.06	0.1
Mercaptan Sulfur, wt %	N/A	0.001	0.001	0.00	0.000
Hydrogen, Mass %	N/A	N/A	13.5	N/A	N/A
Distillation, °C					
IBP	N/A	N/A	133	N/A	N/A
10 % Pt	N/A	182	169	181	194
50 % Pt	N/A	212	211	211	220
90 % Pt	N/A	249	260	250	248
FBP	N/A	274	327	269	263
Residue, Vol %	N/A	1.0	N/A	1.5	1.0
Loss, Vol %	N/A	0.5	N/A	1.0	1.2
Gravity, °API	N/A	N/A	N/A	N/A	N/A
Density, Kg/m^3	833	810	823	810	815
Freezing Point, °C	N/A	-46	-51	-45	-44
Flash Point, °C	N/A	42	61	44	57
Kinematic Viscosity, cSt					
@ -20°C	N/A	6	5.9	5	7
@ 40°C	N/A	1.87	1.90	1.72	1.89
Net Heat of Combustion, Mj/Kg	N/A	43.3	43.1	42.8	43.4
Existent Gum, mg/100mL	N/A	0.6	4.0	0.9	2.2
Particulate Matter, mg/L	N/A	1.0	0.3	2.2	0.1
FSII, Vol %	N/A	0.15	0.05	0.11	0.00
Vapor Pressure, Kpa	N/A	N/A	N/A	N/A	N/A
Lead, g/L	N/A	N/A	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	93-F-374	93-F-539	93-F-610	93-F-609	93-F-338
TAN, mg KOH/g	0.005	N/A	N/A	N/A	N/A
Aromatics, Vol %	17	N/A	N/A	N/A	N/A
Olefins, Vol %	1.5	N/A	N/A	N/A	N/A
Sulfur, Mass %	0.04	N/A	0.00	0.1	0.003
Mercaptan Sulfur, wt %	0.001	N/A	N/A	0.001	N/A
Hydrogen, Mass %	14.2	N/A	N/A	N/A	N/A
Distillation, °C					
IBP	131	N/A	N/A	N/A	N/A
10 % Pt	176	69	70	88	69
50 % Pt	223	100	101	105	100
90 % Pt	269	108	109	117	108
FBP	316	125	127	171	124
Residue, Vol %	N/A	1.2	1.5	1.2	1.4
Loss, Vol %	N/A	0.5	0.3	0.5	0.1
Gravity, °API	43.1	N/A	N/A	N/A	N/A
Density, Kg/m^3	N/A	699	700	708	701
Freezing Point, °C	-48	-58	-80	-80	-80
Flash Point, °C	60	N/A	N/A	N/A	N/A
Kinematic Viscosity, cSt					
@ -20°C	N/A	N/A	N/A	6	N/A
@ 40°C	1.79	1.12	0.66	0.64	1.12
Net Heat of Combustion, Mj/Kg	43.1	43.8	45.3	45.3	48.0
Existent Gum, mg/100mL	0.0	N/A	1.0	1	N/A
Particulate Matter, mg/L	6.0	N/A	N/A	0.2	N/A
FSII, Vol %	0.07	N/A	N/A	0.0	N/A
Vapor Pressure, Kpa	N/A	42	37.1	28.0	44.8
Lead, g/L	N/A	N/A	0.9	0.9	0.7

Table 10. Specification Test Data (continued)

PROPERTY	93-F-644	93-F-551	93-F-449	93-F-464	93-F-638
TAN, mg KOH/g	N/A	N/A	N/A	N/A	N/A
Aromatics, Vol %	10	N/A	N/A	N/A	N/A
Olefins, Vol %	N/A	N/A	N/A	N/A	N/A
Sulfur, Mass %	0.00	N/A	0.003	0.03	0.13
Mercaptan Sulfur, wt %	N/A	N/A	N/A	N/A	N/A
Hydrogen, Mass %	N/A	N/A	N/A	N/A	N/A
Distillation, °C					
IBP	N/A	N/A	N/A	N/A	N/A
10 % Pt	68	72	46	46	58
50 % Pt	101	96	99	99	101
90 % Pt	113	104	158	158	148
FBP	151	130	205	205	186
Residue, Vol %	1.0	1.5	N/A	N/A	N/A
Loss, Vol %	1.1	0.1	N/A	N/A	N/A
Gravity, °API	N/A	N/A	N/A	N/A	N/A
Density, Kg/m^3	706	702	740	744	742
Freezing Point, °C	-80	-80	N/A	N/A	N/A
Flash Point, °C	N/A	N/A	N/A	N/A	N/A
Kinematic Viscosity, cSt					
@ -20°C	N/A	N/A	N/A	N/A	N/A
@ 40°C	0.68	0.55	0.63	N/A	0.62
Net Heat of Combustion, Mj/Kg	43.5	43.6	N/A	N/A	N/A
Existent Gum, mg/100mL	N/A	N/A	N/A	N/A	N/A
Particulate Matter, mg/L	N/A	N/A	N/A	N/A	N/A
FSII, Vol %	N/A	N/A	N/A	N/A	N/A
Vapor Pressure, Kpa	43	44	8.6	7.7	7.4
Lead, g/L	0.6	0.9	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	93-F-591	93-F-653	93-F-640	93-F-586	93-F-625
TAN, mg KOH/g	0.12	N/A	0.004	N/A	0.003
Aromatics, Vol %	12	12	11	N/A	9
Olefins, Vol %	0.7	1.3	1.1	N/A	0.9
Sulfur, Mass %	0.00	N/A	N/A	N/A	0.01
Mercaptan Sulfur, wt %	0.00	N/A	0.001	N/A	0.001
Hydrogen, Mass %	14.4	14.5	N/A	N/A	14.4
Distillation, °C					
IBP	30	35	25	20	N/A
10 % Pt	59	65	72	77	59
50 % Pt	175	160	129	137	100
90 % Pt	233	234	232	239	142
FBP	278	291	288	287	159
Residue, Vol %	N/A	N/A	N/A	N/A	1.3
Loss, Vol %	N/A	N/A	N/A	N/A	0.2
Gravity, °API	N/A	N/A	N/A	N/A	N/A
Density, Kg/m^3	761	758	762	759	748
Freezing Point, °C	-61	-59	-61	-58	-80
Flash Point, °C	N/A	50	60	N/A	N/A
Kinematic Viscosity, cSt					
@ -20°C	N/A	N/A	N/A	N/A	N/A
@ 40°C	N/A	N/A	0.91	0.77	0.82
Net Heat of Combustion, Mj/Kg	43.6	43.6	N/A	N/A	N/A
Existent Gum, mg/100mL	1.8	0.0	0.4	N/A	N/A
Particulate Matter, mg/L	0.4	N/A	N/A	N/A	N/A
FSII, Vol %	0.15	0.15	0.09	0.09	0.1
Vapor Pressure, Kpa	2.6	2.2	14	2.8	14
Lead, g/L	N/A	N/A	N/A	N/A	N/A

Table 10. Specification Test Data (continued)

PROPERTY	93-F-643
TAN, mg KOH/g	N/A
Aromatics, Vol %	N/A
Olefins, Vol %	N/A
Sulfur, Mass %	N/A
Mercaptan Sulfur, wt %	N/A
Hydrogen, Mass %	N/A
Distillation, °C	
IBP	N/A
10 % Pt	59
50 % Pt	100
90 % Pt	142
FBP	159
Residue, Vol %	1.3
Loss, Vol %	0.2
Gravity, °API	N/A
Density, Kg/m^3	748
Freezing Point, °C	-80
Flash Point, °C	N/A
Kinematic Viscosity, cSt	
@ -20°C	N/A
@ 40°C	N/A
Net Heat of Combustion, Mj/Kg	43.3
Existent Gum, mg/100mL	N/A
Particulate Matter, mg/L	N/A
FSII, Vol %	N/A
Vapor Pressure, Kpa	46
Lead, g/L	0.

Appendix E Examples of Full and Time-Segmented Chromatograms of Selected Fuel Samples

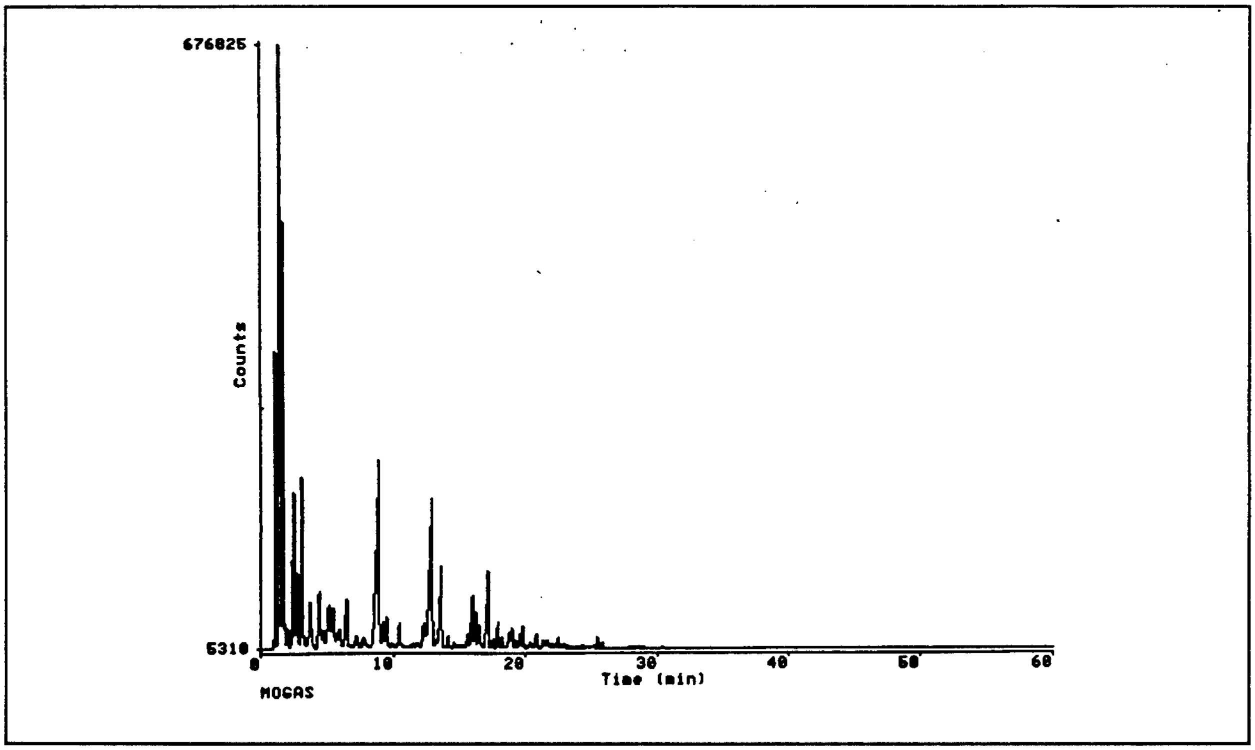

Figure 1. Full Chromatogram of a MOGAS Sample

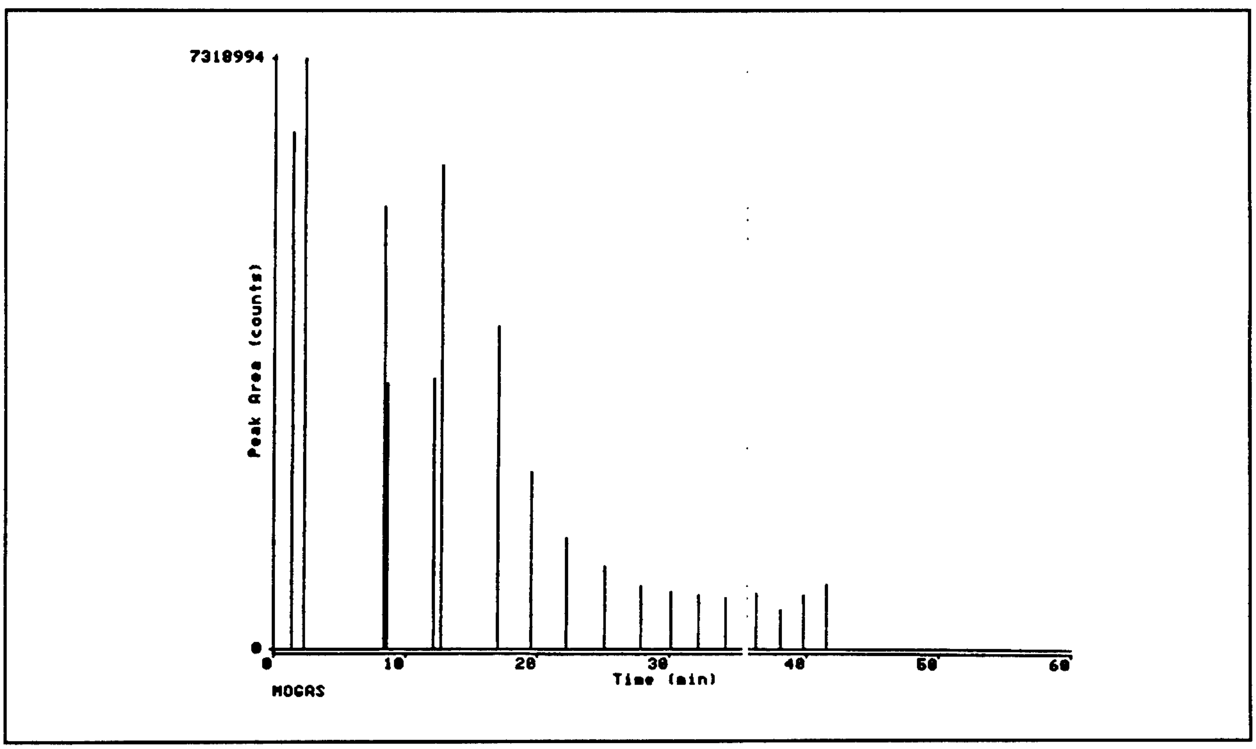

Figure 2. Time-Segmented Chromatogram of a MOGAS Sample

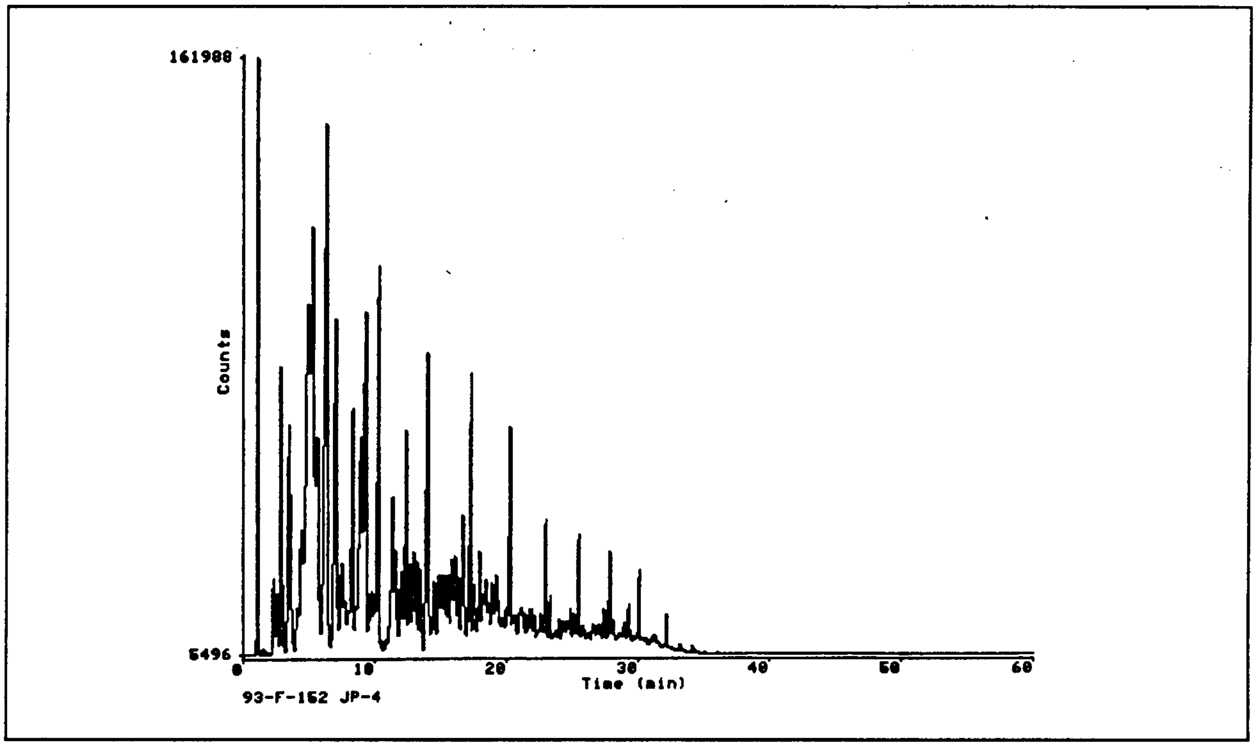

Figure 3. Full Chromatogram of a JP-4 Sample

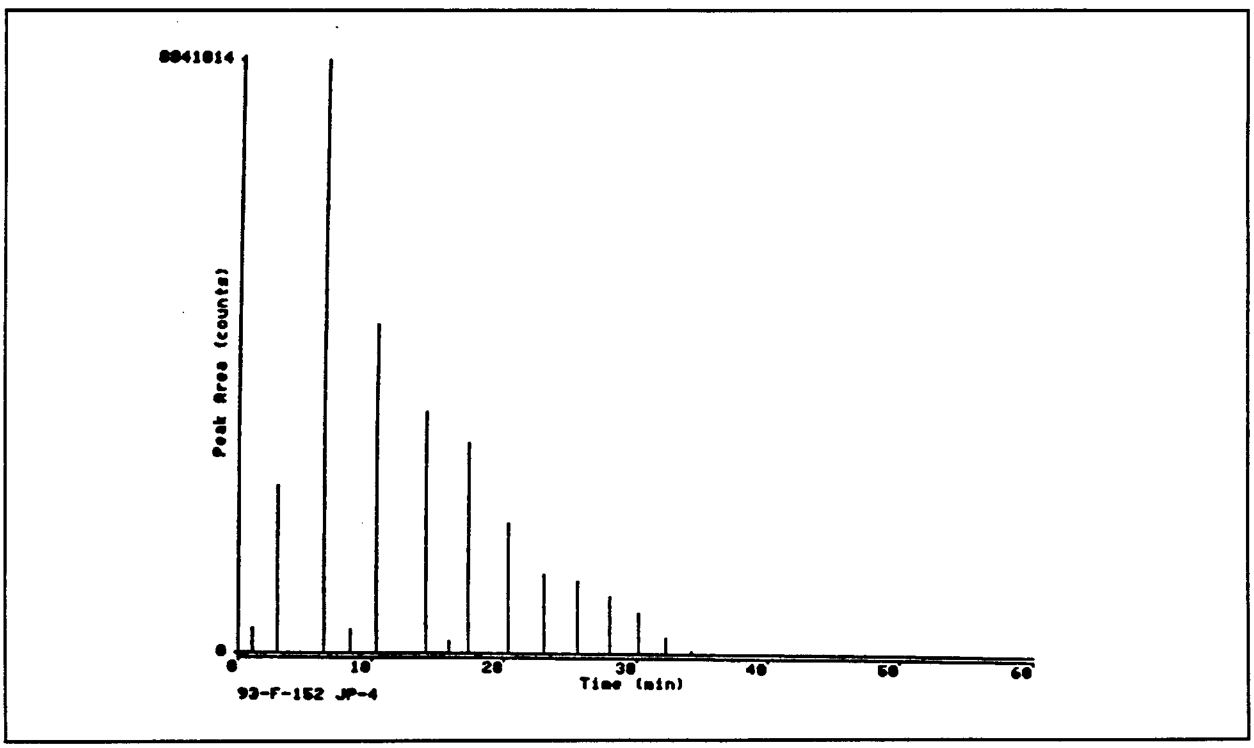

Figure 4. Time-Segmented Chromatogram of a JP-4 Sample

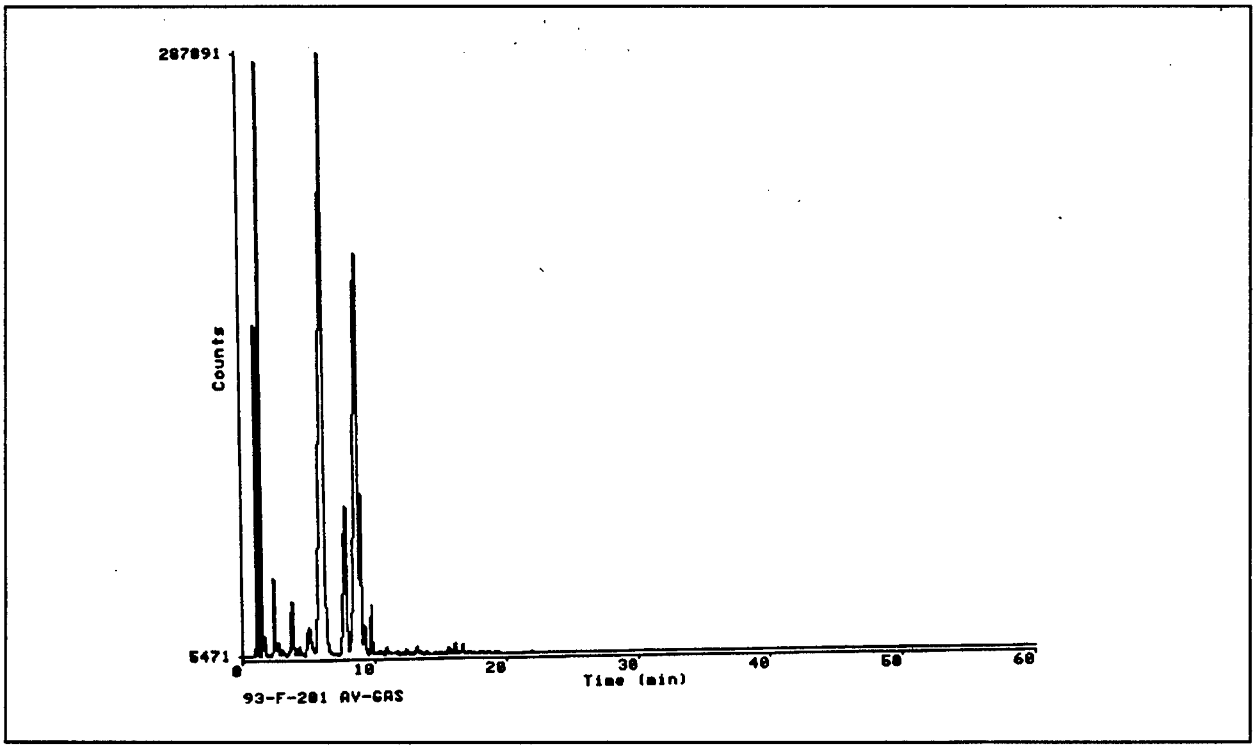

Figure 5. Full Chromatogram of an AVGAS Sample

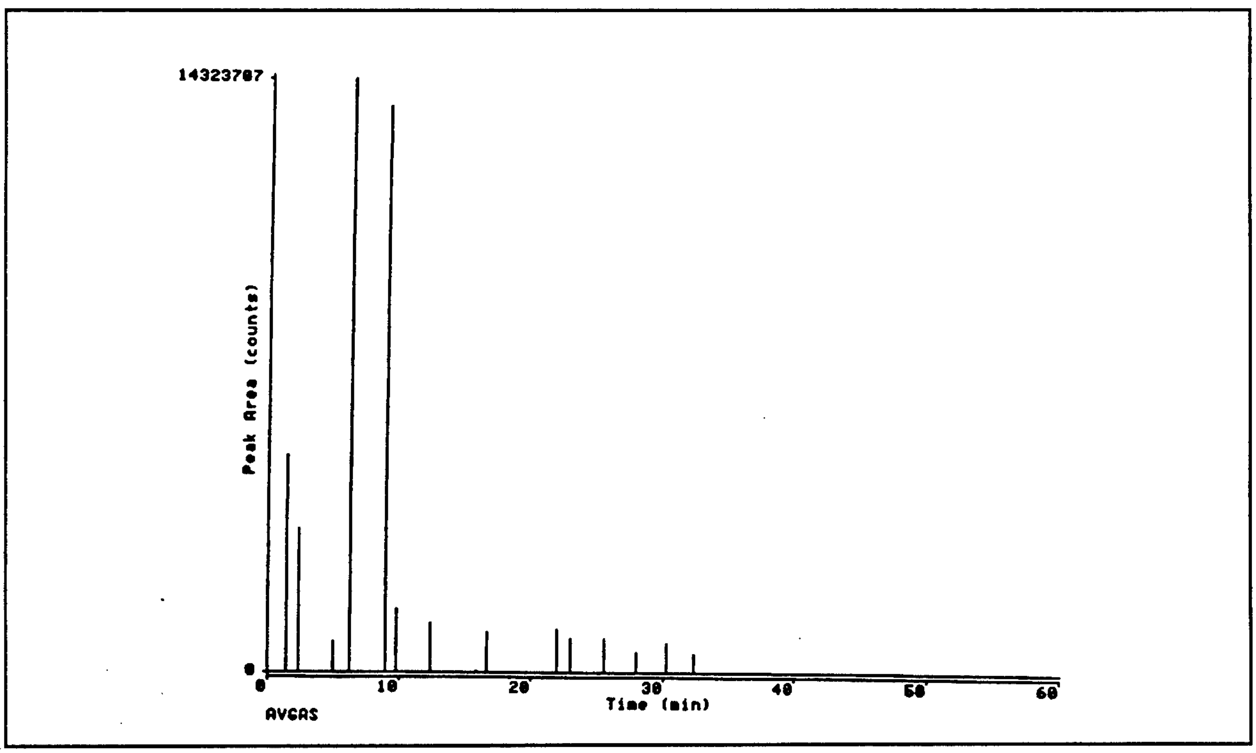

Figure 6. Time-Segmented Chromatogram of an AVGAS Sample

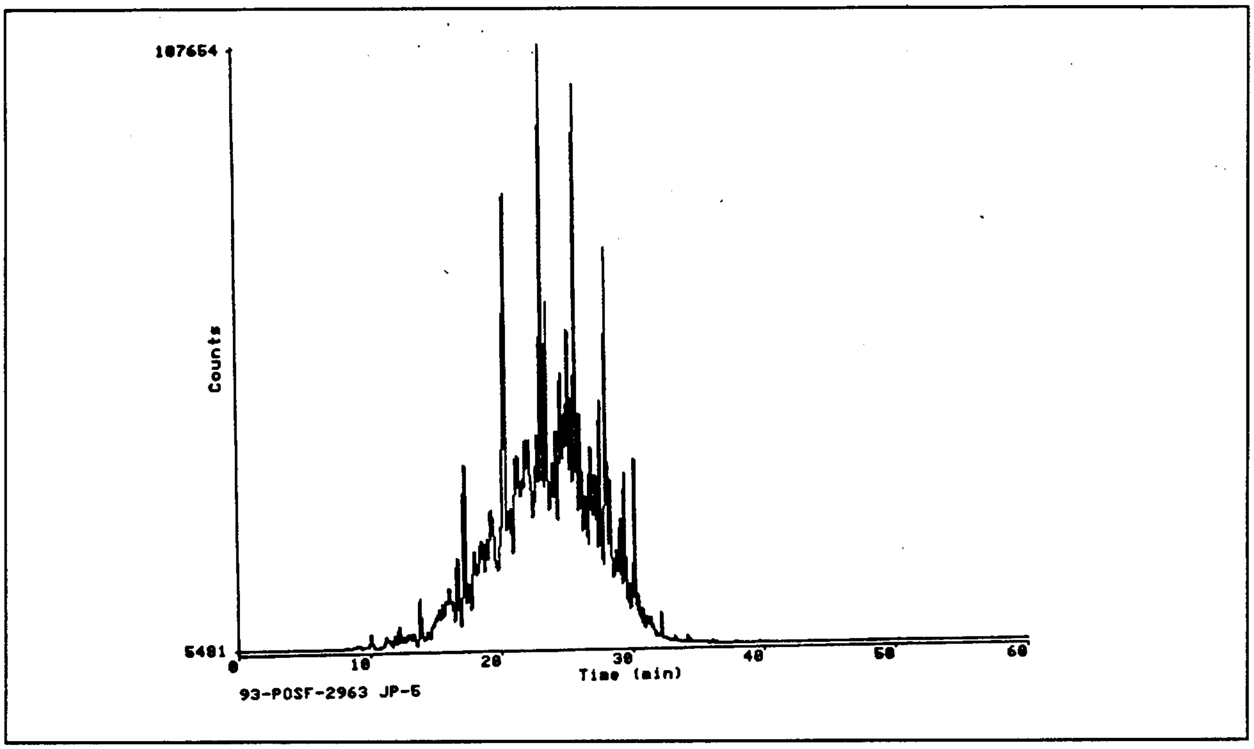

Figure 7. Full Chromatogram of a JP-5 Sample

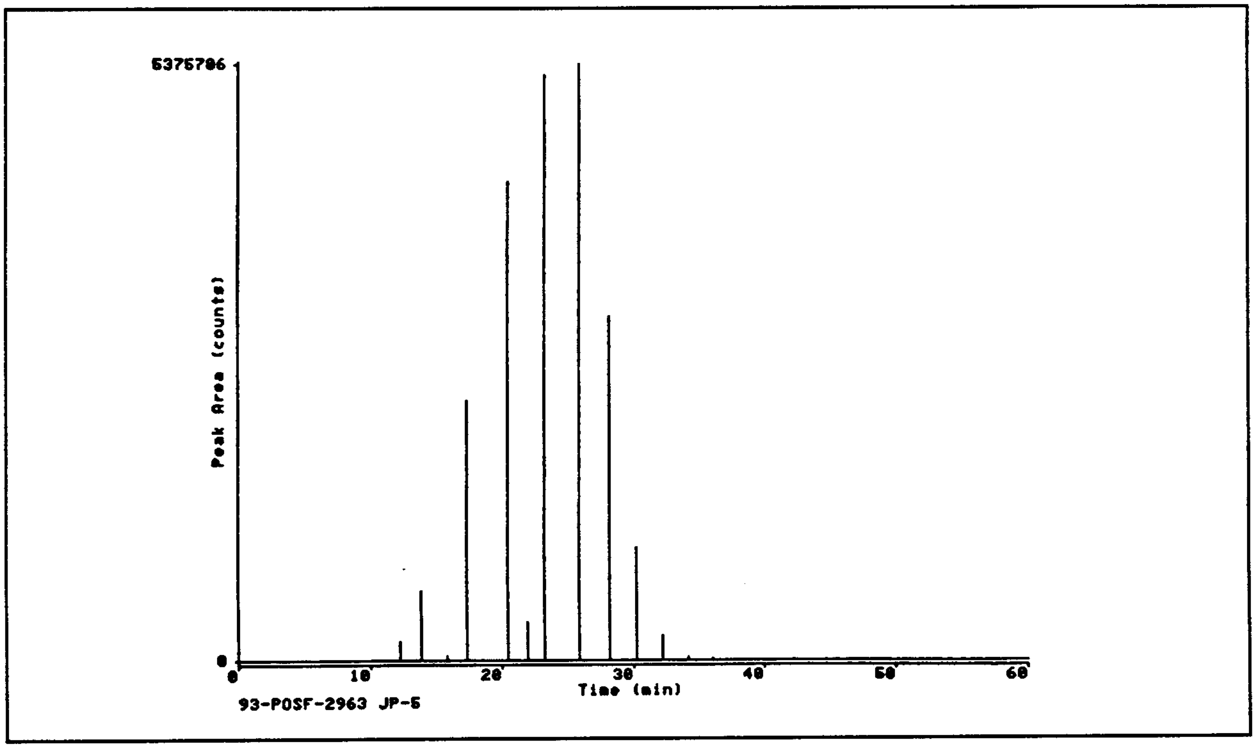

Figure 8. Time-Segmented Chromatogram of a JP-5 Sample

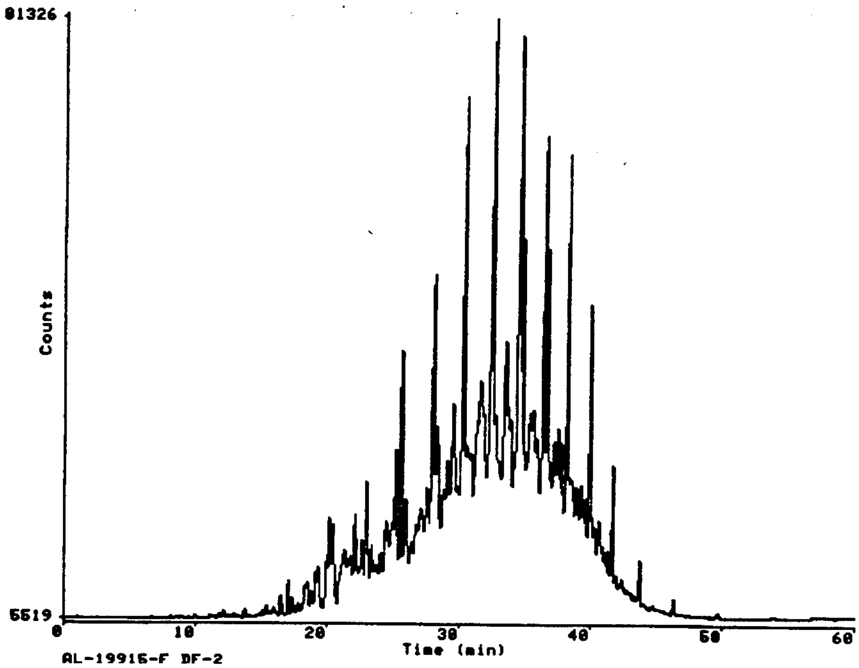

Figure 9. Full Chromatogram of a DF-2 Sample

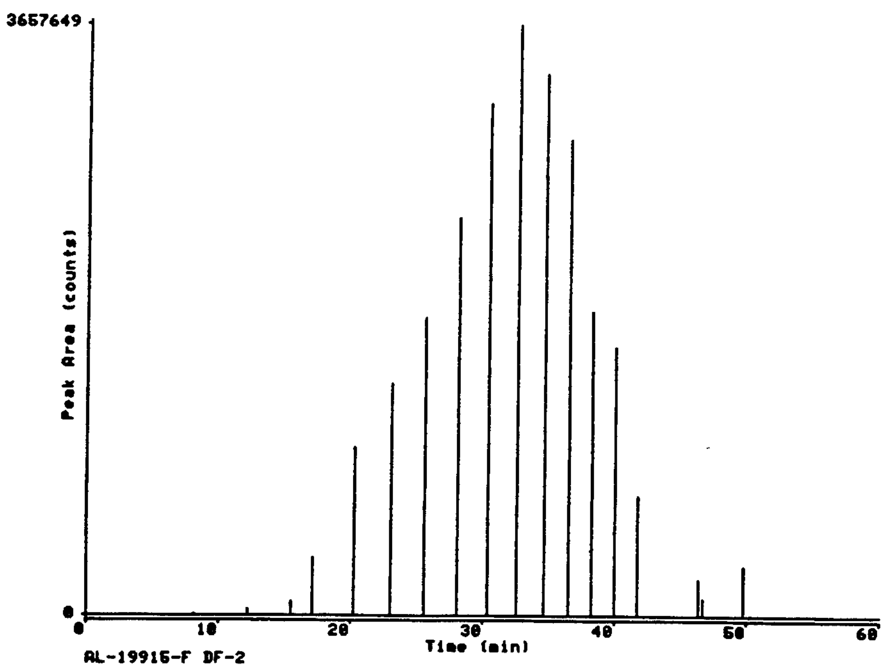

Figure 10. Time-Segmented Chromatogram of a DF-2 Sample

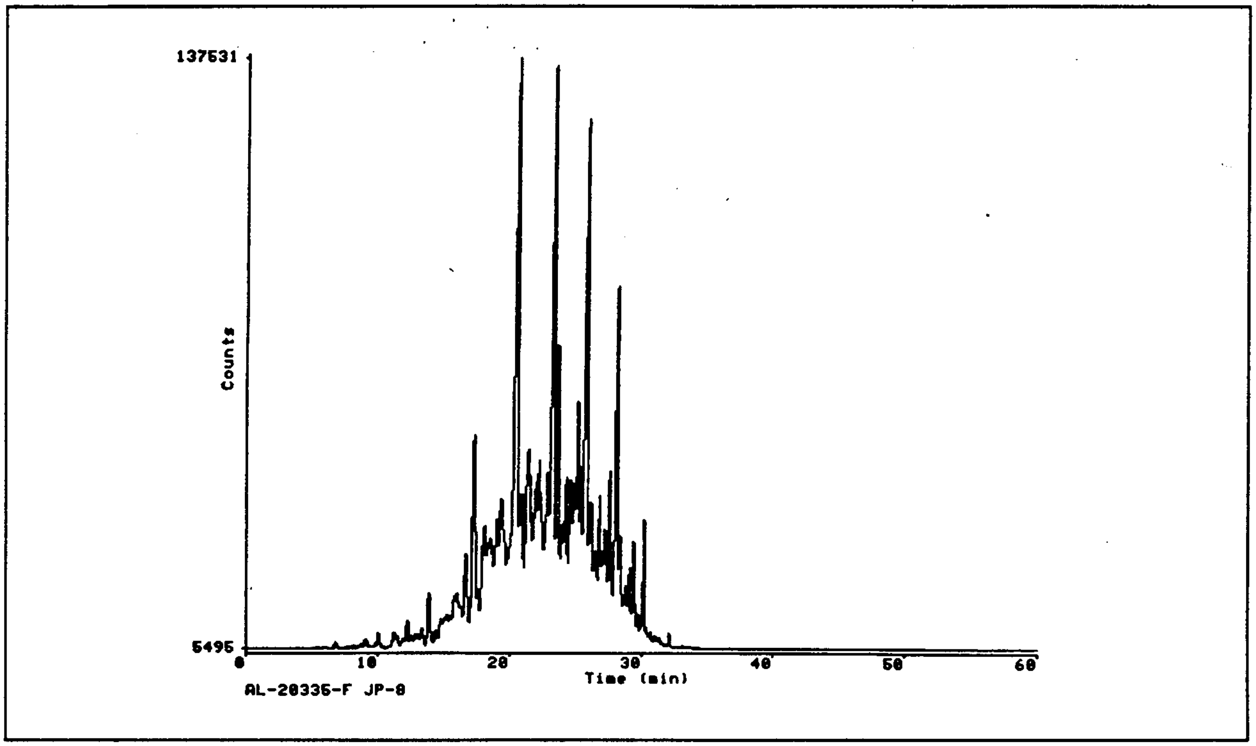

Figure 11. Full Chromatogram of a JP-8 Sample

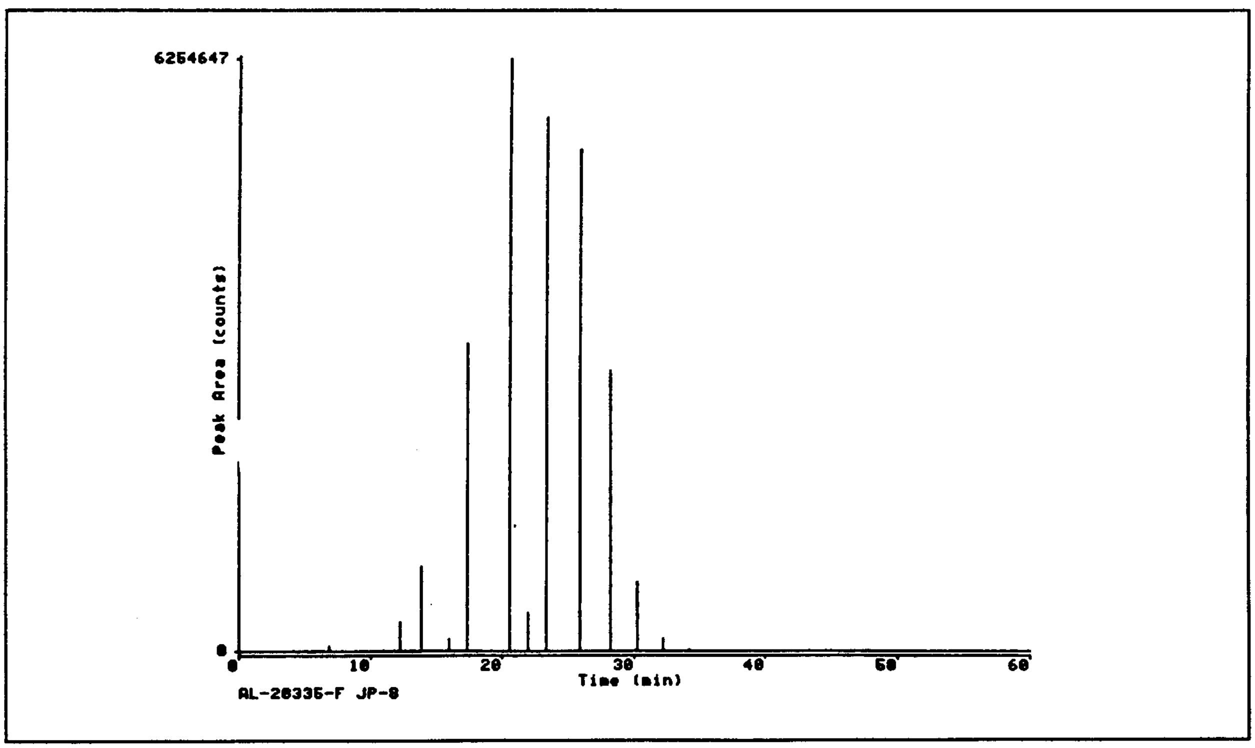

Figure 12. Time-Segmented Chromatogram of a JP-8 Sample

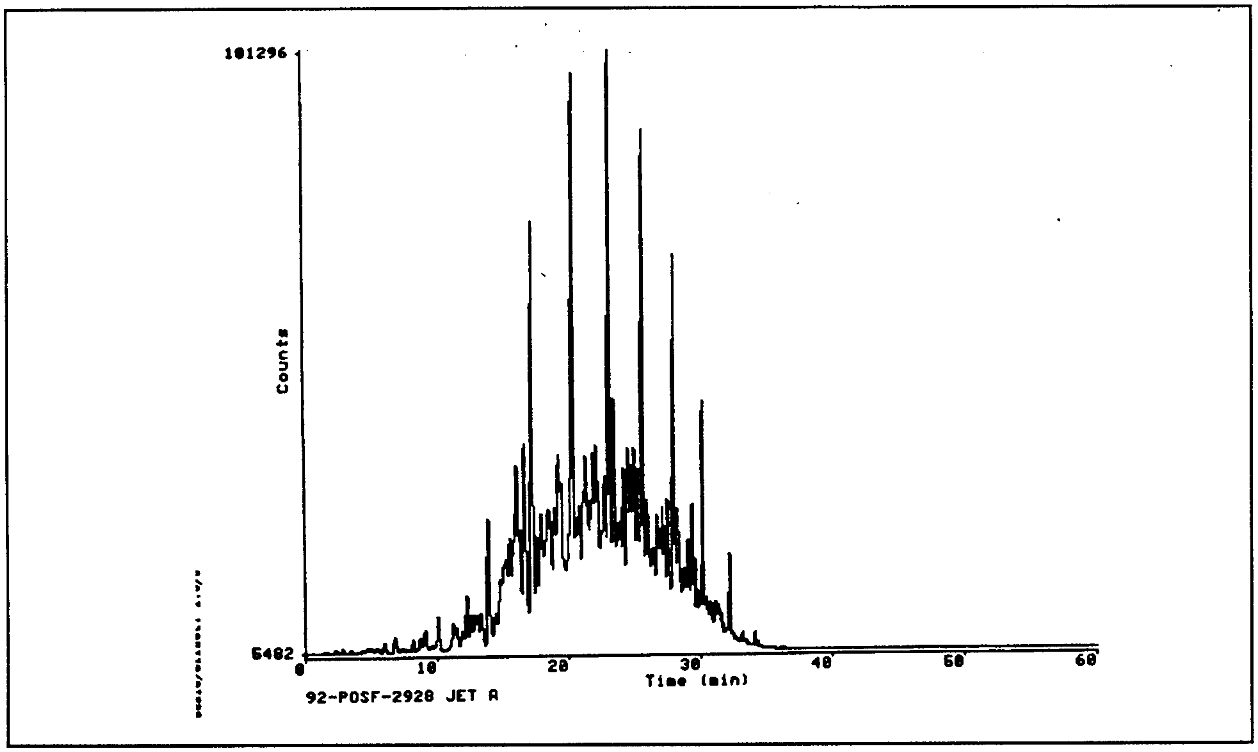

Figure 13. Full Chromatogram of a Jet A Sample

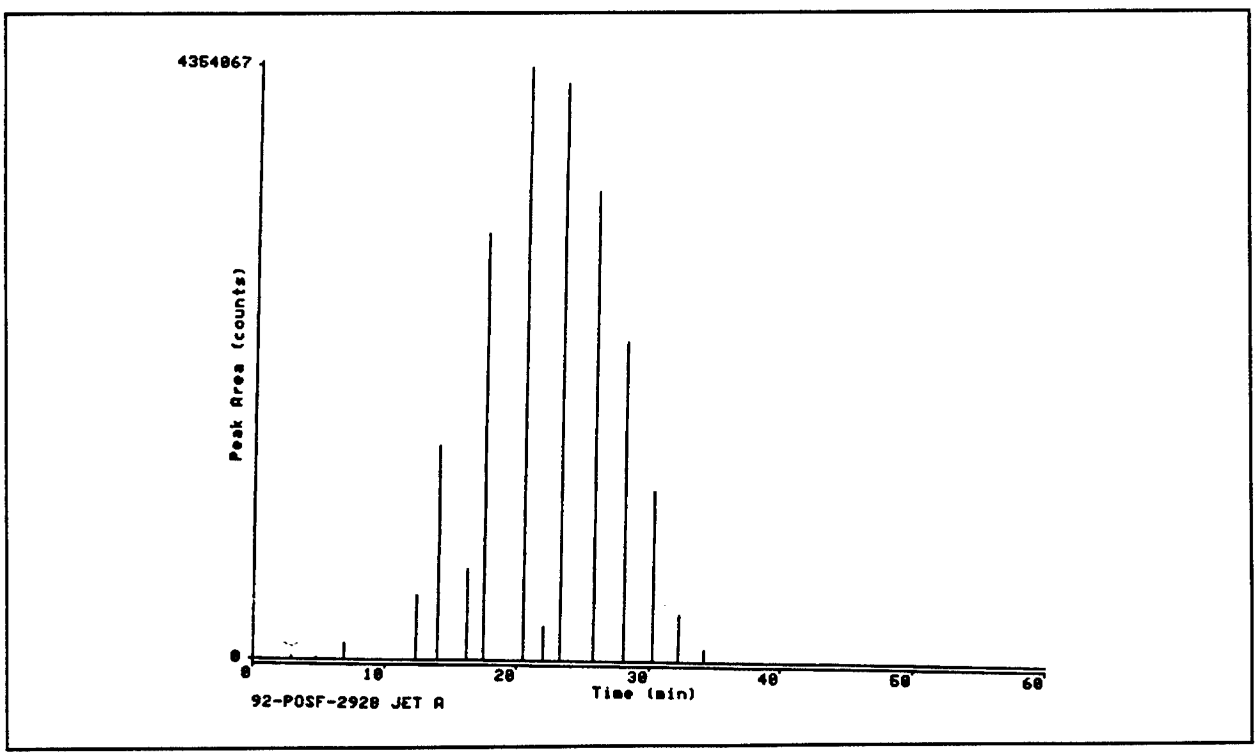

Figure 14. Time-Segmented Chromatogram of a Jet A Sample

Appendix F Repeatability of GLC Analyses

Table 11. Repeatability of GLC Analyses

MIXTURE 1: 10/90 % DF-2/JP-4							
TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5	AVE.	STD.	COEFF.
2.741	2.693	2.677	2.538	2.610	2.652	0.079	0.030
7.667	7.632	7.654	6.648	6.800	7.280	0.510	0.071
16.271	17.209	17.515	15.606	15.682	16.457	0.872	0.053
10.519	10.124	10.046	11.493	11.412	10.719	0.694	0.065
9.662	9.687	9.855	9.671	9.528	9.681	0.116	0.012
7.039	7.242	7.249	7.360	7.285	7.235	0.119	0.017
5.654	5.944	5.924	6.000	5.882	5.881	0.134	0.023
5.212	5.389	5.434	5.357	5.250	5.328	0.094	0.018
5.145	4.840	4.856	5.323	5.154	5.064	0.209	0.041
4.390	4.283	4.279	4.564	4.454	4.394	0.120	0.027
3.079	3.143	3.112	3.410	3.379	3.225	0.157	0.049
2.481	2.302	2.257	2.524	2.510	2.415	0.125	0.052
1.863	1.947	1.892	1.947	1.970	1.924	0.045	0.023
1.730	1.471	1.437	1.693	1.703	1.607	0.141	0.088
1.590	1.552	1.513	1.619	1.563	1.567	0.040	0.026
1.787	1.739	1.695	1.738	1.750	1.742	0.033	0.019
1.915	1.879	1.818	1.883	2.028	1.905	0.077	0.041
2.016	1.885	1.900	1.745	1.806	1.870	0.103	0.055
1.271	1.227	1.207	1.839	1.907	1.490	0.351	0.236
7.967	7.813	7.679	7.041	7.283	7.557	0.384	0.058

Table 11. Repeatability of GLC Analyses (continued)

MIXTURE 2: 10/90 % MOGAS/JP-4							
TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5	AVE.	STD.	COEFF.
2.721	2.771	2.709	2.832	1.919	2.590	0.378	0.146
9.819	9.904	9.952	9.851	8.318	9.569	0.701	0.073
19.150	21.032	20.175	21.067	19.412	20.167	0.889	0.044
11.521	10.915	11.810	10.915	13.187	11.670	0.933	0.080
14.025	14.500	14.659	14.511	14.874	14.514	0.312	0.022
6.707	6.929	7.016	7.014	7.173	6.968	0.170	0.024
6.165	6.442	6.390	6.350	6.389	6.347	0.107	0.017
5.666	6.107	6.006	6.067	5.979	5.965	0.175	0.029
5.374	5.328	5.177	5.321	5.195	5.279	0.088	0.017
4.397	4.552	4.406	4.567	4.398	4.464	0.087	0.020
3.050	3.085	3.077	3.090	3.275	3.115	0.090	0.029
2.065	2.041	2.065	2.037	2.056	2.053	0.013	0.006
1.779	1.719	1.770	1.700	1.770	1.748	0.036	0.020
1.235	1.322	1.360	1.332	1.697	1.389	0.178	0.128
1.502	1.354	1.371	1.300	0.964	1.298	0.201	0.155
1.558	1.499	1.557	1.539	1.426	1.516	0.056	0.037
1.977	0.000	0.000	0.000	1.966	0.789	1.080	1.360
0.000	0.498	0.501	0.509	0.000	0.302	0.275	0.913
1.290	0.000	0.000	0.000	0.000	0.258	0.577	2.240
0.000	0.000	0.000	0.000	0.000	0.000	UNDEF	UNDEF

Table 11. Repeatability of GLC Analyses (continued)

MIXTURE 3: 10/90 % JET A/JP-4							
TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5	AVE.	STD.	COEFF.
2.514	2.443	1.908	2.004	1.920	2.159	.0.296	0.137
10.003	9.449	8.835	9.667	7.772	9.145	0.878	0.096
20.292	20.675	20.503	21.219	19.290	20.396	0.707	0.035
11.710	10.347	10.493	11.764	12.439	11.351	0.898	0.079
9.765	9.261	9.662	9.709	9.625	9.604	0.199	0.021
8.253	8.247	8.589	8.361	8.412	8.372	0.140	0.017
7.595	7.908	8.002	7.729	7.831	7.813	0.158	0.020
6.910	7.266	7.490	7.132	7.265	7.213	0.212	0.030
6.448	6.861	7.010	6.676	6.768	6.768	0.210	0.031
4.910	5.371	5.439	5.024	5.224	5.194	0.225	0.043
3.023	3.414	3.425	3.100	3.592	3.311	0.240	0.724
2.181	2.147	2.133	1.898	2.103	2.092	0.112	0.054
1.730	1.789	1.756	1.550	1.649	1.695	0.096	0.057
1.364	1.356	1.348	1.182	1.813	1.413	0.236	0.167
1.288	1.402	1.253	1.170	0.949	1.212	0.169	0.140
0.000	1.551	1.649	1.383	1.421	1.201	0.680	0.566
1.550	0.513	0.505	0.433	1.926	0.985	0.700	0.711
0.464	0.000	0.000	0.000	0.000	0.093	0.208	2.240
0.000	0.000	0.000	0.000	0.000	0.000	UNDEF	UNDEF
0.000	0.000	0.000	0.000	0.000	0.000	UNDEF	UNDEF

Table 11. Repeatability of GLC Analyses (continued)

MIXTURE 4: 10/90 % MOGAS/JP-4							
TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5	AVE.	STD.	COEFF.
1.762	1.647	1.644	1.512	1.587	1.630	0.092.	0.056
2.411	2.238	2.273	2.062	2.241	2.245	0.124	0.055
3.612	3.378	3.444	3.130	3.386	3.390	0.173	0.051
4.081	3.855	3.921	0.000	3.894	3.150	1.760	0.600
4.131	3.974	4.046	7.364	3.992	4.701	1.490	0.317
5.319	5.256	5.279	5.229	5.284	5.273	0.034	0.006
6.125	6.100	6.138	6.164	6.092	6.124	0.029	0.005
6.652	6.851	6.919	7.260	6.936	6.924	0.219	0.032
7.883	8.012	7.985	8.051	7.956	7.977	0.063	0.008
8.362	8.716	8.679	9.271	8.684	8.742	0.329	0.038
8.075	8.361	8.501	8.700	8.517	8.431	0.233	0.028
7.790	7.928	7.634	8.449	7.605	7.881	0.343	0.044
6.396	6.686	7.043	7.050	7.052	6.845	0.296	0.043
4.674	5.221	4.811	5.239	4.816	4.952	0.260	0.052
3.844	3.924	3.919	4.215	3.909	3.962	0.145	0.037
3.844	3.924	3.919	4.215	3.909	3.962	0.145	0.037
3.548	3.550	3.571	3.507	3.557	3.547	0.024	0.007
3.334	2.988	3.246	2.866	3.213	3.129	0.195	0.062
2.068	2.189	2.056	1.960	2.030	2.060	0.0831	0.040
2.150	2.023	1.568	1.829	2.019	1.918	0.227	0.118

Table 11. Repeatability of GLC Analyses (continued)

MIXTURE 5: 10/90 % JP-4 /JET A							
TRIAL 1	**TRIAL 2**	**TRIAL 3**	**TRIAL 4**	**TRIAL 5**	**AVE.**	**STD.**	**COEFF.**
1.001	1.101	0.979	0.989	0.849	0.984	.0.090	0.091
2.083	2.257	2.040	2.054	1.773	2.041	0.174	0.085
3.847	4.047	3.735	3.753	3.295	3.735	0.276	0.074
4.881	5.121	4.800	4.818	4.250	4.774	0.320	0.067
7.396	7.677	7.505	7.509	6.676	7.353	0.391	0.053
13.977	14.014	14.382	14.339	12.650	13.872	0.708	0.051
15.560	15.223	15.781	15.720	14.330	15.323	0.596	0.039
15.362	14.556	14.782	14.739	13.777	14.643	0.571	0.039
12.462	11.961	12.669	12.632	12.163	12.377	0.307	0.025
8.821	8.812	8.967	8.950	8.270	8.764	0.285	0.032
5.389	5.271	5.312	5.335	4.925	5.246	0.185	0.035
2.822	2.975	2.812	2.826	2.505	2.788	0.172	0.062
1.781	1.942	1.753	1.766	1.538	1.756	0.144	0.082
1.349	1.456	1.299	1.304	1.007	1.283	0.167	0.130
1.289	1.498	1.407	1.349	1.102	1.329	0.148	0.112
1.492	1.594	1.324	1.460	1.388	1.452	0.103	0.071
0.000	0.000	0.000	0.458	1.654	0.422	0.716	1.700
0.488	0.497	0.454	0.000	1.660	0.620	0.618	0.997
0.000	0.000	0.000	0.000	0.000	0.000	UNDEF	UNDEF
0.000	0.000	0.000	0.000	6.187	0.000	2.770	2.240

Appendix G Time-Segmented GLC Results for Fuel Samples

Table 12. Time-Segmented GLC Results

GLC CELL REGIONS	POSF-2959 JET A	POSF-2928 JET A	POSF-2926 JET A	POSF-2747 JET A	POSF-2930 JET A	POSF-2827 JET A
1	0.011	0.008	0.077	0.009	0.020	0.026
2	0.130	0.103	0.120	0.014	0.075	0.079
3	0.670	0.550	0.739	0.018	0.535	0.570
4	2.332	0.000	2.701	0.042	2.628	0.000
5	9.334	9.104	5.227	2.056	6.660	9.380
6	20.251	16.978	12.459	23.614	15.628	15.591
7	21.718	19.610	17.150	39.725	19.158	19.003
8	19.286	20.222	19.114	23.966	17.251	16.983
9	14.866	15.455	16.371	8.215	14.465	14.652
10	8.536	10.470	13.793	1.760	12.055	12.120
11	2.349	5.562	8.748	0.405	8.031	8.105
12	0.495	1.513	2.928	0.122	2.844	2.858
13	0.019	0.407	0.568	0.038	0.619	0.622
14	0.001	0.017	0.006	0.012	0.014	0.000
15	0.000	0.001	0.000	0.003	0.000	0.000
16	0.000	0.000	0.000	0.001	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000

Table 12. Time-Segmented GLC Results (continued)

GLC CELL REGIONS	POSF-2922 JET A	93-F-173 JET A	POSF-2931 JET A-1	POSF-2936 JP-8	AL-20011-F JP-8	AL-20335-F JP-8
1	0.003	0.017	0.021	0.001	0.010	0.000
2	0.014	0.112	0.076	0.021	0.101	0.009
3	0.113	0.602	0.546	0.119	0.583	0.166
4	0.772	2.055	2.310	1.040	2.188	1.171
5	2.702	6.091	6.930	3.242	7.007	3.464
6	10.607	14.580	15.689	10.166	16.894	12.876
7	23.221	19.325	19.268	21.953	20.339	24.070
8	25.332	18.861	17.231	24.826	18.407	23.275
9	21.356	16.043	14.397	21.929	15.727	20.345
10	11.179	11.625	12.067	12.581	10.681	11.280
11	3.124	6.947	8.016	3.369	5.637	2.799
12	0.865	2.482	2.800	0.697	1.672	0.471
13	0.362	0.723	0.637	0.051	0.454	0.045
14	0.147	0.187	0.013	0.003	0.142	0.009
15	0.111	0.074	0.000	0.001	0.067	0.005
16	0.061	0.118	0.000	0.000	0.048	0.011
17	0.031	0.158	0.000	0.000	0.018	0.004
18	0.000	0.000	0.000	0.000	0.000	0.001
19	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000

Table 12. Time-Segmented GLC Results (continued)

GLC CELL REGIONS	AL-20123-F JP-8	AL-20336-F JP-8	AL-19903-F JP-8	POSF-2934 JP-8	93-L-100 DF-2	AL-20221-F DF-2
1	0.000	0.000	0.000	0.031	0.121	0.051
2	0.000	0.012	0.006	0.422	0.116	0.102
3	0.016	0.183	0.167	1.513	0.338	0.296
4	0.544	1.283	1.198	3.297	1.224	0.578
5	8.753	4.149	3.506	10.850	2.415	0.997
6	19.476	14.637	13.040	18.074	5.092	2.274
7	24.659	24.192	24.287	16.933	7.093	3.657
8	21.823	23.090	23.316	16.852	8.588	4.799
9	13.704	18.857	20.211	15.396	10.678	7.749
10	6.559	11.115	11.093	12.447	12.382	12.485
11	2.487	2.178	2.723	3.825	11.599	13.514
12	1.060	0.298	0.436	0.358	11.214	12.945
13	0.462	0.005	0.017	0.000	9.268	11.686
14	0.189	0.000	0.001	0.000	6.633	9.247
15	0.113	0.000	0.000	0.000	5.108	7.341
16	0.070	0.000	0.000	0.000	3.772	6.425
17	0.058	0.000	0.000	0.000	2.377	3.874
18	0.009	0.000	0.000	0.000	0.930	1.326
19	0.015	0.000	0.000	0.000	0.447	0.395
20	0.000	0.000	0.000	0.000	0.581	0.259

Table 12. Time-Segmented GLC Results (continued)

GLC CELL REGIONS	93-F-152 JP-4	DEFESS JP-4	POSF-2963 PF-5	POSF-2817 JP5	93-F-284 JP-5	AL-20243-F JET FUEL
1	1.278	3.837	0.000	0.006	0.000	0.001
2	8.298	11.760	0.001	0.028	0.002	0.014
3	29.460	19.019	0.014	0.153	0.023	0.458
4	17.594	15.611	0.724	0.826	0.603	3.438
5	11.952	14.429	2.733	2.424	4.738	6.728
6	11.025	12.163	10.238	7.046	12.792	16.323
7	6.490	7.138	18.859	18.670	21.682	21.125
8	4.038	6.091	24.566	24.274	24.179	17.976
9	3.736	5.286	23.419	23.187	22.047	13.277
10	2.982	3.360	13.587	15.692	10.381	9.090
11	2.135	1.046	4.440	6.239	2.973	5.971
12	0.848	0.244	1.006	1.411	0.490	2.986
13	0.124	0.015	0.142	0.044	0.069	1.499
14	0.013	0.000	0.041	0.000	0.012	0.510
15	0.010	0.000	0.018	0.000	0.008	0.116
16	0.009	0.000	0.004	0.000	0.001	0.035
17	0.011	0.000	0.001	0.000	0.000	0.009
18	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000

Table 12. Time-Segmented GLC Results (continued)

GLC CELL REGIONS	POSF-2818 JP-7	POSF-2799 JP-TS	93-F-201 AVGAS	93-F-312 JP-5	93-F-310 JP-5	93-F-326 MOGAS
1	0.000	0.000	9.840	0.000	1.143	13.098
2	0.001	0.022	5.321	0.000	2.099	13.301
3	0.022	0.252	49.077	4.931	3.472	17.394
4	0.028	1.783	33.627	8.103	3.867	9.758
5	0.098	9.104	1.038	10.158	6.211	9.644
6	4.464	29.705	0.753	10.448	11.089	7.946
7	30.004	30.537	0.222	11.329	16.625	6.369
8	29.800	12.143	0.081	10.877	17.865	5.246
9	19.784	8.552	0.036	10.72	16.273	4.051
10	8.388	5.971	0.002	8.738	9.019	2.036
11	3.385	1.885	0.003	7.243	3.906	2.017
12	0.856	0.045	0.000	6.196	2.150	1.837
13	0.334	0.000	0.000	5.718	2.099	1.255
14	0.072	0.000	0.000	2.840	1.394	1.180
15	0.021	0.000	0.000	2.699	1.217	1.179
16	0.002	0.000	0.000	0.000	1.572	1.495
17	0.000	0.000	0.000	0.000	0.000	2.192
18	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000

Table 12. Time-Segmented GLC Results (continued)

GLC CELL REGIONS	93-F-142 JET A	93-F-313 JP-5	93-F-279 AVGAS	93-F-351 JP-8	93-F-412 JP-4	93-F-307 MOGAS
1	1.136	0.000	7.974	0.788	3.784	13.906
2	2.234	3.115	5.751	2.137	9.469	15.894
3	3.529	5.000	23.126	3.269	19.629	11.876
4	4.764	5.776	24.040	4.460	13.168	14.552
5	6.990	6.853	5.880	6.123	11.181	12.978
6	11.739	10.203	4.060	12.411	8.735	8.712
7	14.526	14.149	3.412	16.390	6.067	4.785
8	13.817	13.720	2.945	15.611	5.442	3.005
9	11.277	12.558	2.903	14.256	5.319	2.266
10	9.416	7.906	2.377	8.509	4.065	1.722
11	6.327	4.426	2.362	4.575	3.016	1.555
12	2.984	3.456	2.008	2.127	2.101	1.480
13	2.147	2.923	2.043	1.736	1.400	1.396
14	1.456	2.281	1.901	1.004	1.549	1.528
15	1.382	2.282	1.715	0.943	1.416	1.065
16	1.654	2.939	2.104	1.414	1.488	1.506
17	0.000	2.413	0.000	2.129	1.993	1.774
18	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	2.090	0.354	0.000
20	4.622	0.000	5.403	0.027	0.025	0.000

Table 12. Time-Segmented GLC Results (continued)

GLC CELL REGIONS	93-F-289 AVGAS	93-F-311 JP-5	93-F-304 JET A	93-F-233 JP-4	93-F-339 MOGAS	93-F-295 AVGAS
1	11.424	0.826	2.265	2.191	2.591	8.433
2	7.579	2.236	4.389	7.985	6.559	11.407
3	33.166	3.638	7.163	20.093	5.119	30.200
4	33.369	3.840	8.097	24.701	4.312	34.269
5	2.651	6.425	7.938	18.947	61.558	2.726
6	2.282	10.983	9.775	9.169	4.297	2.146
7	0.000	16.203	10.677	4.028	2.467	1.857
8	4.119	23.483	9.858	2.626	2.062	1.717
9	1.765	16.186	9.220	2.335	1.826	1.518
10	1.107	9.515	8.208	2.067	1.569	1.329
11	1.568	3.920	6.689	1.975	1.479	1.324
12	0.971	2.568	5.206	1.394	1.500	0.926
13	0.000	1.755	4.770	1.297	1.269	0.000
14	0.000	1.189	2.689	1.191	1.385	0.855
15	0.000	1.121	2.370	0.000	1.089	1.065
16	0.000	1.510	0.000	0.000	1.019	0.229
17	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000
20	0.685	0.000	0.000	0.000	0.000	0.000

Table 12. Time-Segmented GLC Results (continued)

GLC CELL REGIONS	93-F-280 JET A	93-F-306 MOGAS	AL-19850-F JP-8	AL-19915-F DF-2	AL-20027-F TURBINE	93-F-347 JP-4
1	0.985	17.006	0.002	0.004	0.024	2.289
2	2.381	12.318	0.027	0.008	0.079	7.743
3	3.892	8.908	0.273	0.034	0.243	17.575
4	4.525	12.117	1.743	0.140	1.001	14.972
5	5.462	11.415	4.776	0.329	3.058	12.558
6	10.203	7.779	12.152	1.390	8.151	9.925
7	14.422	4.113	22.301	4.188	11.326	6.898
8	15.308	2.501	23.877	5.684	15.698	5.560
9	14.819	2.220	21.641	7.293	18.503	4.706
10	10.355	1.713	9.839	9.733	14.175	4.454
11	6.904	1.471	1.966	12.515	10.364	3.014
12	3.955	1.387	0.570	14.451	6.405	3.832
13	2.452	1.399	0.329	13.239	4.065	3.186
14	1.924	1.243	0.227	11.647	2.651	2.408
15	1.000	1.242	0.145	7.442	1.578	0.000
16	1.410	1.433	0.088	6.581	1.176	0.000
17	0.000	1.761	0.051	2.901	0.751	0.000
18	0.000	1.789	0.002	0.878	0.344	0.000
19	0.000	1.687	0.000	0.395	0.172	0.000
20	0.000	6.496	0.000	1.219	0.267	0.000

Table 12. Time-Segmented GLC Results (continued)

GLC CELL REGIONS	93-F-444 JET A	93-F-665 JET A	93-F-560 JET A	93-F-374 JP-5	93-F-668 JP-5	93-F-624 JP-4
1	0.9030	0.9050	0.8540	0.6200	0.0000	1.8800
2	1.7290	1.7500	1.7270	1.6900	1.4140	8.8330
3	3.1020	3.0300	3.2640	2.7600	2.2620	20.977
4	4.6980	4.0630	4.8330	3.6750	2.9210	16.143
5	6.5260	4.8400	6.1420	5.3590	4.8430	13.974
6	12.540	8.9460	11.214	10.945	11.659	10.622
7	14.716	14.762	16.376	16.795	18.674	6.5310
8	12.538	16.764	15.149	17.872	16.153	3.9290
9	11.094	15.476	12.871	14.872	13.318	3.4990
10	9.1270	13.178	9.2360	9.8990	7.5580	2.9950
11	6.3140	7.8900	6.5560	5.7740	4.6160	2.4870
12	3.3080	2.8480	3.5520	3.2180	3.0480	1.9110
13	1.7780	1.5940	1.6980	1.9300	2.0660	1.7410
14	1.2290	1.2510	1.3300	1.4170	1.6050	1.3560
15	1.1380	1.1860	1.2640	1.2410	1.1360	1.3470
16	1.3330	1.0930	1.3070	1.4300	1.2830	1.3220
17	1.6920	0.4220	1.5600	0.000	1.2350	0.4540
18	1.7350	0.000	0.000	0.4820	1.4540	0.0000
19	0.000	0.000	1.0670	0.000	1.0420	0.0000
20	4.4990	0.000	0.000	0.000	3.7130	0.0000

Table 12. Time-Segmented GLC Results (continued)

GLC CELL REGIONS	93-F-625 JP-4	93-F-640 JP-4	93-F-591 JP-4	93-F-653 JP-4	93-F-643 AVGAS	93-F-551 AVGAS
1	2.5660	2.0460	2.9410	2.2600	10.671	7.3600
2	12.050	11.859	17.753	15.055	13.804	10.414
3	17.643	20.878	10.025	13.476	8.2530	41.290
4	10.772	10.579	0.2710	8.4990	17.951	23.394
5	9.5620	9.1780	11.652	9.7180	27.043	2.8940
6	8.6470	8.6530	9.5640	10.289	5.5270	2.8680
7	8.2320	7.7660	11.801	9.4730	2.6870	2.1940
8	7.5710	6.7750	11.864	8.9110	2.0230	1.9210
9	6.8830	6.0010	8.7610	7.5330	1.8720	1.8060
10	4.8650	4.4830	4.1610	4.3450	1.0550	1.8590
11	2.8650	2.9920	1.9070	2.5750	0.0000	1.1630
12	1.9080	2.0990	1.7350	1.6460	0.0000	0.0000
13	1.7220	1.8070	1.6310	1.6430	0.0000	0.7210
14	1.3640	1.4020	1.2630	1.2850	0.0000	0.0000
15	1.3020	1.3600	1.2100	1.3000	0.7220	0.6190
16	1.5390	1.6200	1.5840	1.5000	1.1230	1.1030
17	0.5110	0.5010	0.0000	0.4920	0.4250	0.3960
18	0.000	0.0000	1.8770	0.0000	0.0000	0.0000
19	0.000	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.000	0.0000	0.0000	0.0000	6.8440	0.0000

Table 12. Time-Segmented GLC Results (continued)

GLC CELL REGIONS	93-F-644 AVGAS	93-F-338 AVGAS	93-F-609 AVGAS	93-F-610 AVGAS	93-F-539 AVGAS	93-F-464 MOGAS
1	7.8780	7.9040	5.1180	8.0830	8.2850	11.455
2	9.2580	7.1970	5.8470	6.8790	7.8120	15.435
3	29.311	34.469	30.343	30.588	33.728	13.039
4	31.904	29.363	33.932	29.596	30.756	10.667
5	3.8990	3.2630	3.8210	3.4770	3.1780	10.416
6	2.7960	2.6840	3.8020	2.8830	2.6520	11.331
7	2.0920	2.4270	2.6940	2.6780	2.4530	6.2840
8	1.7510	1.9750	1.8570	2.0470	1.9640	3.2480
9	1.7070	1.9370	1.8930	2.0810	2.0200	2.5560
10	1.4900	1.9040	1.8560	1.8540	1.8940	1.8550
11	1.4500	1.4720	1.4260	1.7690	1.3780	1.7500
12	1.2200	1.4590	1.4300	1.5690	0.0000	1.5850
13	1.3990	1.6600	1.5910	1.7340	1.4590	1.4950
14	1.1130	0.0000	1.2650	0.0000	0.0000	1.4080
15	1.0550	0.6650	1.1900	0.9360	0.7390	1.1530
16	1.2730	1.1730	1.4500	1.4440	1.2100	1.5220
17	0.4050	0.4500	0.4870	0.4650	0.4720	1.7620
18	0.0000	0.0000	0.0000	1.9160	0.0000	1.8080
19	0.0000	0.0000	0.0000	0.0000	0.0000	1.2300
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 12. Time-Segmented GLC Results (continued)

GLC CELL REGIONS	93-F-638 MOGAS	93-F-449 MOGAS	93-F-586 JP-4	93-F-402 JP-4	93-F-290 AVGAS
1	9.6830	12.845	3.1120	2.760	6.591
2	12.163	11.918	9.2800	9.468	8.431
3	15.778	12.831	20.564	20.969	29.405
4	16.705	14.722	10.989	11.028	36.212
5	13.233	14.151	10.600	9.217	4.610
6	6.4830	8.0580	8.3550	7.207	2.976
7	3.4350	4.6560	7.4440	6.510	2.068
8	2.2250	3.0270	6.8690	6.078	1.753
9	2.0090	2.4430	6.5440	5.957	1.701
10	1.7060	1.9100	5.1610	4.808	1.446
11	1.4950	1.6650	3.1860	3.401	1.463
12	1.5120	1.7470	1.9070	2.385	0.751
13	1.4720	1.6090	1.5870	1.868	0.724
14	1.3670	1.4470	1.2430	1.656	1.204
15	1.1850	1.2550	1.2180	1.030	0.664
16	1.4950	1.7320	1.4570	1.496	0.000
17	1.7820	1.9500	0.0000	2.162	0.000
18	1.8430	2.0330	0.4840	0.000	0.000
19	0.0000	0.0000	0.0000	0.000	0.000
20	4.4280	0.0000	0.0000	0.000	0.000

Analysis of Removed Samples

Table 15. Analysis of Removed Samples

SAMPLE #	FUEL TYPE	PREDICTED FUEL TYPE
92-POSF-2928	JET A	JP-8 GROUP
93-F-444	JET A	JP-8 GROUP
93-F-665	JET A	JP-8 GROUP
93-POSF-2747	JET A	JP-8 GROUP
AL-20335-F	JP-8	JP-8 GROUP
92-POSF-2934	JP-8	JP-8 GROUP
93-F-280	JET A	JP-8 GROUP
93-F-311	JP-5	JP-8 GROUP
93-F-310	JP-5	JP-8 GROUP
93-F-289	AVGAS	AVGAS
93-F-290	AVGAS	AVGAS
93-F-201	AVGAS	AVGAS
93-F-640	JP-4	JP-4
DEJESS	JP-4	JP-4
93-F-402	JP-4	JP-4
93-F-307	MOGAS	MOGAS
93-F-326	MOGAS	MOGAS
AL-20221-F	DF-2	DF-2

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